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U.S. ARMY ENGINEER SCHOOL

FORT BELVOIR, VIRGINIA

Construction Management

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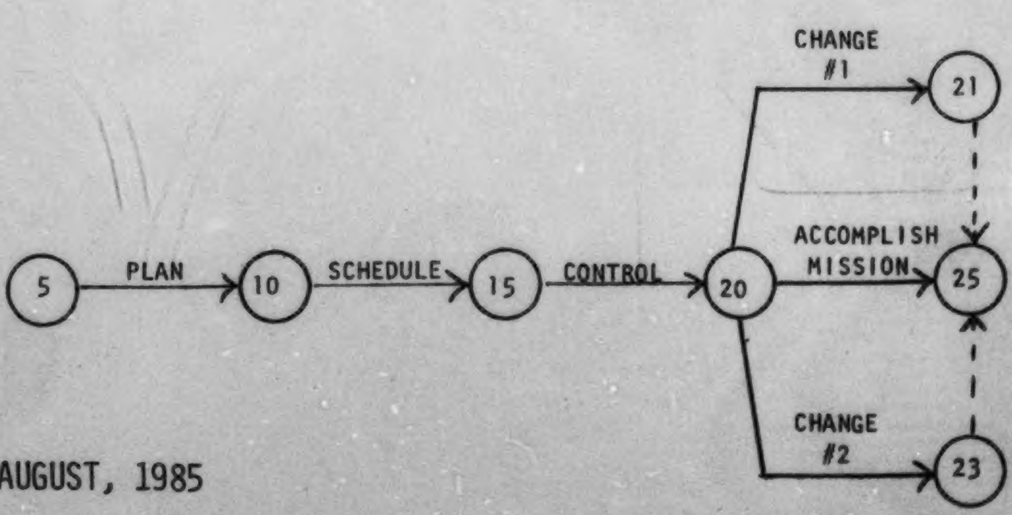
CHANGE #1
21
5
PLAN
10
SCHEDULE
15
CONTROL
20
ACCOMPLISH MISSION
25
CHANGE #2
23

AUGUST, 1985

READEX FICHE best copy available

FOREWORD

This workbook is designed to help the student master the techniques of Engineering Management. It is intended that the workbook can be used either in a classroom or self-paced learning mode. Each lesson is divided into five main sections to facilitate study and review. These sections are:

1. Lesson objective and student references.

2. Discussion material and an example problem with a detailed explanation of the solution.

3. Practical exercises designed for use in the classroom.

4. Student practical exercises with solutions to give the student practice with the concepts taught during the lesson.

5. Self-evaluation questions.

Classroom Learning Mode.

The material will be presented by the instructor using various teaching techniques. The student will be able to master the material through individual work and instructor-student interaction.

Self-Paced Learning Mode.

The student will be able to master the lesson objective by studying the references and working the practical exercises and tests contained in each lesson. The student will turn in the completed test from each lesson to the instructor when the student feels that the material has been mastered. This test will be used only as a guide of the students' progress and mastery of the material.

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INTRODUCTION

The subject of Engineering Management encompasses a broad spectrum of planning, evaluation and control techniques. Considering the limitations of class time, it has been decided to concentrate on one technique rather than survey numerous methods. The Critical Path Method (CPM) was developed in 1958 specifically for the management of construction projects and was chosen over other techniques because of the applications in planning which are not limited solely to construction projects.

Although the classroom discussion will be oriented toward construction projects, the student should be aware of the broad applications of CPM to planning, evaluation and control of any job or staff action.

PRELIMINARY PLANNING
AND
SITE RECONNAISSANCE

LESSON: **PRELIMINARY PLANNING AND SITE RECONNAISSANCE**

OBJECTIVE: The student, given TM 5-333, will be able to analyze the construction directive; identify the types of information that should be gathered during the site investigation and the effect of this information on the effort required to complete the project.

REFERENCE: TM 5-333, chapter 1, para 1-1 thru 1-21.

STUDENT NOTES

MANAGEMENT CONCEPTS

Definition of Management: The process of getting things done through people.

MANAGEMENT FUNCTIONS:

1. Planning: The development and evaluation of alternatives for successfully completing the mission. It includes the choice of an alternative and the establishment of an orderly sequence for accomplishing the objective. Planning is a DECISION MAKING PROCESS and can be divided into two parts.

a. Preliminary Planning: Provides the engineer with a quick overall picture of the assigned task and information on which to base detailed planning Preliminary planning includes:

(1) Receipt and study of the Construction Directive.

(2) Site investigation.

(3) Operational plan.

b. Detailed Planning: Utilizes the information obtained during preliminary planning to complete the planning process to include:

(1) Listing activities (subtasks) to be accomplished.

(2) An accurate estimate of the material, labor, equipment and duration of each subtask on the activities list.

(3) Developing a network that shows the logical sequence in which each of the activities must be accomplished.

(4) A time analysis to determine the project duration, critical activities, and to provide information for scheduling.

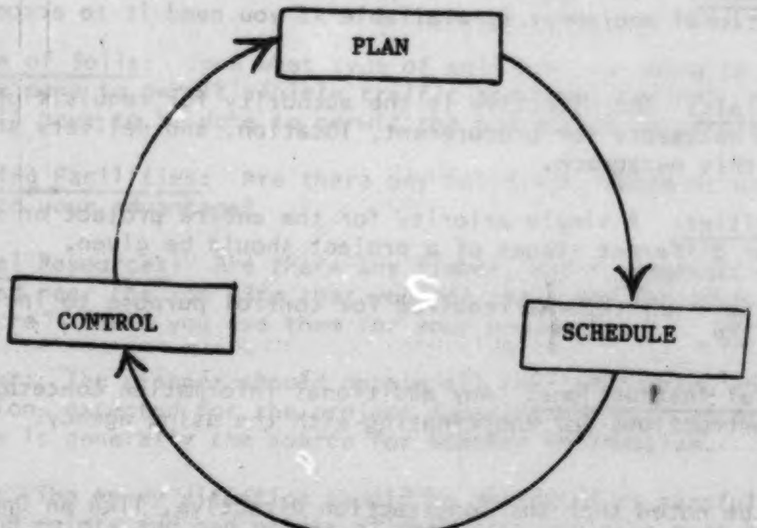
2. Organizing: The establishment of authority relationships to provide for structural coordination. This is normally done for us throug the unit TOE.

3. Staffing: Finding the right person for the job.

4. Directing: Getting your men to work as a team to accomplish the objective. It is essential that you make sure your personnel understand their job and that your NCO's are involved with every phase of the operation.

5. **Controlling:** The effective manager must be able to control the job, and as the situation changes, he must adjust the plan in order to accomplish the mission on schedule. Controlling is a continuing process that starts with the receipt of the Construction Directive and ends when the finished product is accepted. As a manager you must remember that you are the individual responsible for the success or failure of a project. You must be able to provide direction, planning, control of all costs, schedules and resources, and above all - customer satisfaction.

MANAGEMENT CYCLE



PRELIMINARY PLANNING

CONSTRUCTION DIRECTIVE:

The management process starts with the receipt of a directive which is an order to construct, rehabilitate, maintain or destroy some facility. The directive should include a description of the project and include plans and specifications. Regardless of the form of the directive or the amount of detail, the Construction Directive should contain the following items:

a. Mission: The exact assignment with all necessary detail, and may include an implied mission.

b. Location: This may be a definite location, or the directive may require you to select a site in a general area.

c. Time: The start or finish time should be given. If you do the plannin and estimating, you should be the one to determine how long the project will take.

d. Manpower: You should already know what manpower you have available to you. This paragraph tells you what additional manpower is available if needed.

e. Equipment: You know what equipment you have and this paragraph tells you what additional equipment is available if you need it to accomplish the mission.

f. Materials: The directive is the authority for requisitioning materials. The lead time necessary for procurement, location, and delivery should be addressed in this paragraph.

g. Priorities: A single priority for the entire project or separate priorities for different stages of a project should be given.

h. Reports: Any reports required for control purpose to include those in your unit SOP.

i. Special Instructions: Any additional information concerning the project to include instructions for coordinating with the using agency.

***It should be noted that the Construction Directive, like an Operations Order, need not be in writing.

SITE INVESTIGATION:

This is a reconnaissance of the selected site or the selection of a site within a general area. It is used to determine how the environment will effect the effort required to accomplish the project. Part of your site investigation should be a map recon to determine possible sources of materials or facilities prior to departing to site.

On site investigation, the OIC should take with him the S-3 Projects Officer so he can coordinate surveyors, soils analysts and drafting requirements; the user for any revision of design and utilization; his NCOIC or platoon sergeant and if possible, a representative of the S-4 or faculty engineers so the procurement requirements can be discussed and analyzed.

a. Terrain: What are the terrain features of the proposed site? Is it hilly, flat, wooded, swampy or desert, and how will it effect your project?

b. Drainage: What are the drainage characteristics? Is it well drained? What effort will be needed to keep it drained before, during and after construction?

c. Accessibility: What problems will be involved in reaching the site? What effort will be required to permit travel to, from, and within the site? This should include bridge classifications, road clearances, and convoy permits if required.

d. Nature of Soils: Upon what type of soil are you going to build? What will have to be done to permit vehicle traffic and construction? How much additional work will have to be done to permit the project to be completed?

e. Existing Facilities: Are there any buildings, roads or utilities that you could use to your advantage?

f. Natural Resources: Are there any timber, water, aggregate or borrow material located near the job site that you can use? How far away are they? How much is there? Could you use them for your project?

g. Weather: The planner should obtain all the information about the weather conditions expected for the project duration and plan accordingly. The unit S-2 office is generally the source for weather information.

h. Enemy: The enemy situation should be evaluated as carefully as possible. The overall good points and bad points of defending the site must be studied in detail and recommendations made for improvements. The S-2 must be consulted for an update of the enemy situation.

USE OF MILITARY LABOR:

As a manager, you must be aware that there are limitations on the use of military labor on peacetime projects. Regulations specify severe penalties for violations of these limitations. Therefore, it is your responsibility to question a Construction Directive if it appears to violate any of the following limitations:

a. Use of military personnel for the maintenance, repair, alteration, and new construction of real property is limited to projects that will attain and maintain technical unit proficiency, or to projects restricted by security.

b. DA policy prohibits the use of enlisted personnel in competition with civilian labor when it can be practically avoided. Lack of funds is not a valid basis for using military personnel where not otherwise permitted.

c. Military labor costs are not included when determining the level to which a project must be submitted for approval. However, travel and per diem applicable to troop labor plus costs applicable to maintenance and operations of government-owned equipment will be included. The cost of unfunded military labor and equipment depreciation must be accumulated and recorded as part of total project costs.

d. No new work can be performed in a new facility within one year of its completion unless approved by the Department of the Army. An example would be partitions in the orderly room.

OPERATIONAL PLAN:

After studying the Construction Directive and preparing the site investigation notes, the project manager can start preparing an operational plan. This plan includes everything not directly related to the execution of your mission such as administration and logistics/support. These include, but are not limited to:

- a. Movement into construction site.
- b. Transportation of supplies and logistics.
- c. Locating messing, quartering areas, administration areas, workshops, maintenance (POL) shop.
- d. Daily chores such as distribution of mail, paychecks, duties, laundry facilities, etc.
- e. Area security in a tactical environment.
- f. Inclement weather plans such as SQT training or common tasks training or alternate work activities.
- g. Maintenance.
- h. Replacement of casualties.

The only aspect of the project the Operational Plan does not cover is the actual execution of the mission itself. This will be examined by the manager or OIC when the detailed planning for the project is started.

NOTE: A classroom and student practical exercise are omitted in this lesson. An example of a Construction Directive and typical site investigation notes can be found on pages 16 and 17 respectively.

SELF-EVALUATION QUESTIONS PRELIMINARY PLANNING

1. List the five (5) Functions of Management.

a. ______________________ d. ______________________

b. ______________________ e. ______________________

c. ______________________

2. Preliminary planning is the study of the Construction Directive and finding the right man for the job.

TRUE FALSE

3. The Construction Directive is an authorization to requisition materials.

TRUE FALSE

4. Which of the following are normally part of the site investigation?

a. Terrain. c. Enemy situation.

b. Equipment d. Soil.

5. Which of the following would not be considered as part of the operational plan?

a. How to construct the project.
b. Where the workers are going to eat.
c. The security of the job site.
d. Where the supplies will be kept.

6. What two (2) parts of the site investigation notes would normally be obtained from sources other than physically visiting the worksite?

a. ____.

b. ____.

Solutions on page .

STUDENT EVALUATION

1. What aspects of project planning are included in the Operational Plan?

2. Why does the Construction Directive not contain enough information for the manager to begin planning the project? What additional information is needed, and how can it be obtained?

3. What is the project manager required to do if the Construction Directive specifies only a general location for the project?

4. What advantages does the project manager have if the Construction Directive specifies a starting date but no completion date?

SELF-EVALUATION ANSWERS - PRELIMINARY PLANNING

1. a. Planning
   b. Organizing
   c. Staffing
   d. Directing
   e. Controlling

2. False. Finding the right man for the job is part of staffing.

3. True.

4. a, c, d. The equipment available comes from the Construction Directive

5. a. How to construct the project. This is accomplished in the detailed planning for the project.

6. a. Weather.
   b. Enemy situation.

PROJECT PLANNING

6

LESSON: ACTIVITY LIST DEVELOPMENT

OBJECTIVE: The student, using the Construction Directive and Site Investigation Notes, will be able to analyze the project and develop a list of all the activities necessary to complete the mission.

STUDENT NOTES

DETAILED PLANNING

ACTIVITIES LIST: This is the process of dividing a project into time consuming, definable tasks.

a. Activity: Any definable, time consuming part of a project.

b. Preparing an activities list:

(1) Study the plans and specifications and results of the site investigation.

(2) Construct the project mentally or on paper. Remember that the degree of detail will vary with your intended use of the list.

(3) Do NOT consider time, men, order of construction, material, or equipment.

(4) Check the activities list for completeness and accurate descriptions.

c. With each activity there should be a description or definition of what work is to be performed within the activity.

The development of the Activities List is the starting step in Project Management, and the one that frustrates many managers. You must remember the steps in "b" above and start the list with any activity you know. You will find that once the process of constructing the project mentally has begun the activities come to mind very easily. A good practice in developing an activity's list is to name each activity by using a noun and an action verb (two words is all you need for an activity title). For example: assemble trusses is more explanatory and helpful in the description than just trusses, which may be confused as prefab trusses or assemble trusses, etc.

EXAMPLE PROBLEM

FIRST REQUIREMENT: CAREFULLY STUDY THE FOLLOWING CONSTRUCTION DIRECTIVE, SITE INVESTIGATION NOTES AND SITE PLAN.

HEADQUARTERS
111th ENGINEER BATTALION
FORT WHATITSNAME, VA

29 September ____

SUBJECT: Construction Directive No. FWV 85-002C-111

Commander, Company C

1. You will install two culverts per attached plans and specifications.

2. Location: Intersection of Range and Access Roads, Fort Whatitsname, Virginia. See site plan.

3. Time: Construction will begin NLT ______.

4. Additional Manpower and Equipment: Additional hose is available for air compressor.

5. Priority: A

6. Reports: Submit a complete activities list for the project. Progress reports will be submitted IAW SOP.

7. Materials: One hour notice is required for pickup of culverts.

8. Special Instructions: No changes are authorized except thru Bn S-3. The contact officer for the using agency will be 1LT Harris, who can be located at Bldg. 247. Telephone - 42473.

FOR THE COMMANDER:

R. U. FORREAL
CPT, EN
Adjutant

SITE INVESTIGATION NOTES

PROJECT NUMBER: FWV 85-002C-111

1. Terrain: Site is hilly and heavily wooded.

2. Drainage: Site is poorly drained.

3. Accessibility: Both range and access roads are earth surface, but adequate for movement of men and materials. Access road gate is opened at 0700 hours and closed each duty day at 1800 hours. No traffic is expected during construction except for constructing unit.

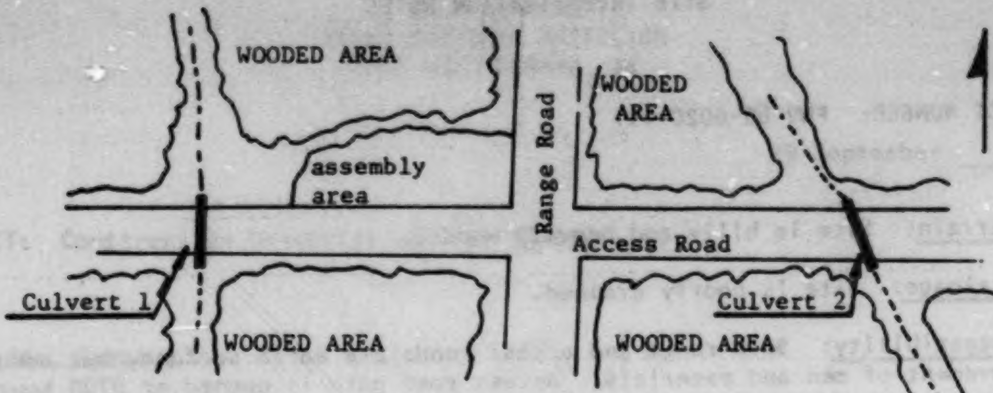
4. Nature of Soil: Well graded and easily compacted.

5. Existing Facilities: Assembly area for culverts is at the northwest corner of intersection of range and access roads. The assembly area is small, so only one culvert at a time can be assembled. Once one is assembled and moved out of the way, another can be assembled.

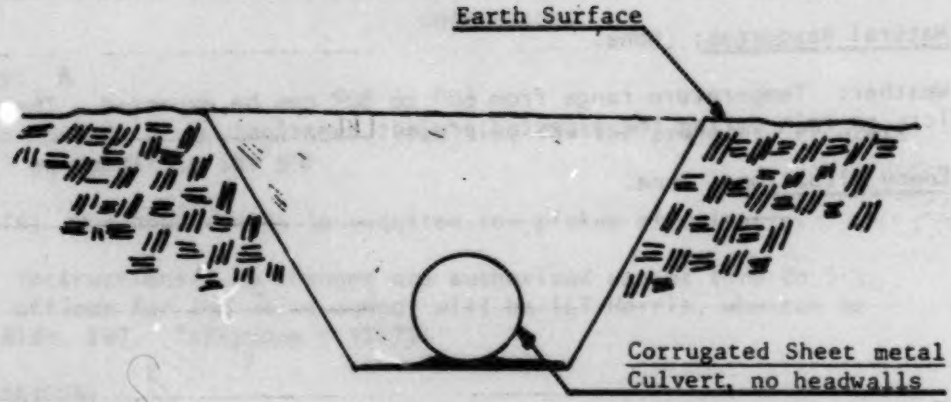
6. Natural Resources: None.

7. Weather: Temperature range from 60° to 80° can be expected. The Bn S-2 predicts no rain during the expected project duration.

8. Enemy Situation: None.


WOODED AREA
WOODED AREA
assembly area
Range Road
Access Road
Culvert 1
Culvert 2
WOODED AREA
WOODED AREA

SITE PLAN


Earth Surface
Corrugated Sheet metal Culvert, no headwalls

CULVERT DETAIL

SECOND REQUIREMENT: DEVELOP AN ACTIVITIES LIST OF AT LEAST 8 ACTIVITIES USING THE SPACE PROVIDED BELOW.

ACTIVITY LIST FOR THE TWO CULVERT PROJECT

	ACTIVITY	DESCRIPTION
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

NOTES

STUDENT PRACTICAL EXERCISE I

HEADQUARTERS
111th COMBAT ENGINEER BATTALION (HVY)
FORT WHATITSNAME, VA

20 February 198_

SUBJECT: Construction Directive No FWV85-07C-111

Commander, Company C

1. You will construct a block office building and parking area per attached plans and specifications.

2. Location: Intersection of Range and Access Roads, Ammunition Storage Area, Fort Whatitsname, VA. See site plan.

3. Time: Construction will begin NLT 15 March 198_.

4. Manpower and Equipment Authorization: Facilities Engineers will excavate, install and backfill gas, water and sewer lines.

5. Priority: A

6. Reports: Submit CPM network to theis HQ NLT 28 February 198_. Weekly progress reports will be submitted IAW SOP.

7. Materials: BOM will be prepared and submitted NLT 28 February 198_. Concrete ready-mix will be furnished by civilian contractor thru Facilities Engineers. 24-hour notice is required for concrete delivery.

8. Special Instructions: No changes are authorized except thru Bn S-3.

FOR THE COMMANDER:

1 Encl
1 Plns, blk bldg

R. U. FORREAL
CPT, EN
Adjutant

SITE INVESTIGATION NOTES

PROJECT NUMBER: FWV85-07C-111

1. Terrain: Site is level and clear.

2. Drainage: Site is well drained by existing ditching.

3. Accessibility: Both Range and Access Roads are hard surface. Access Road gate is opened by 0700 hours and closed at 1800 hours each duty day.

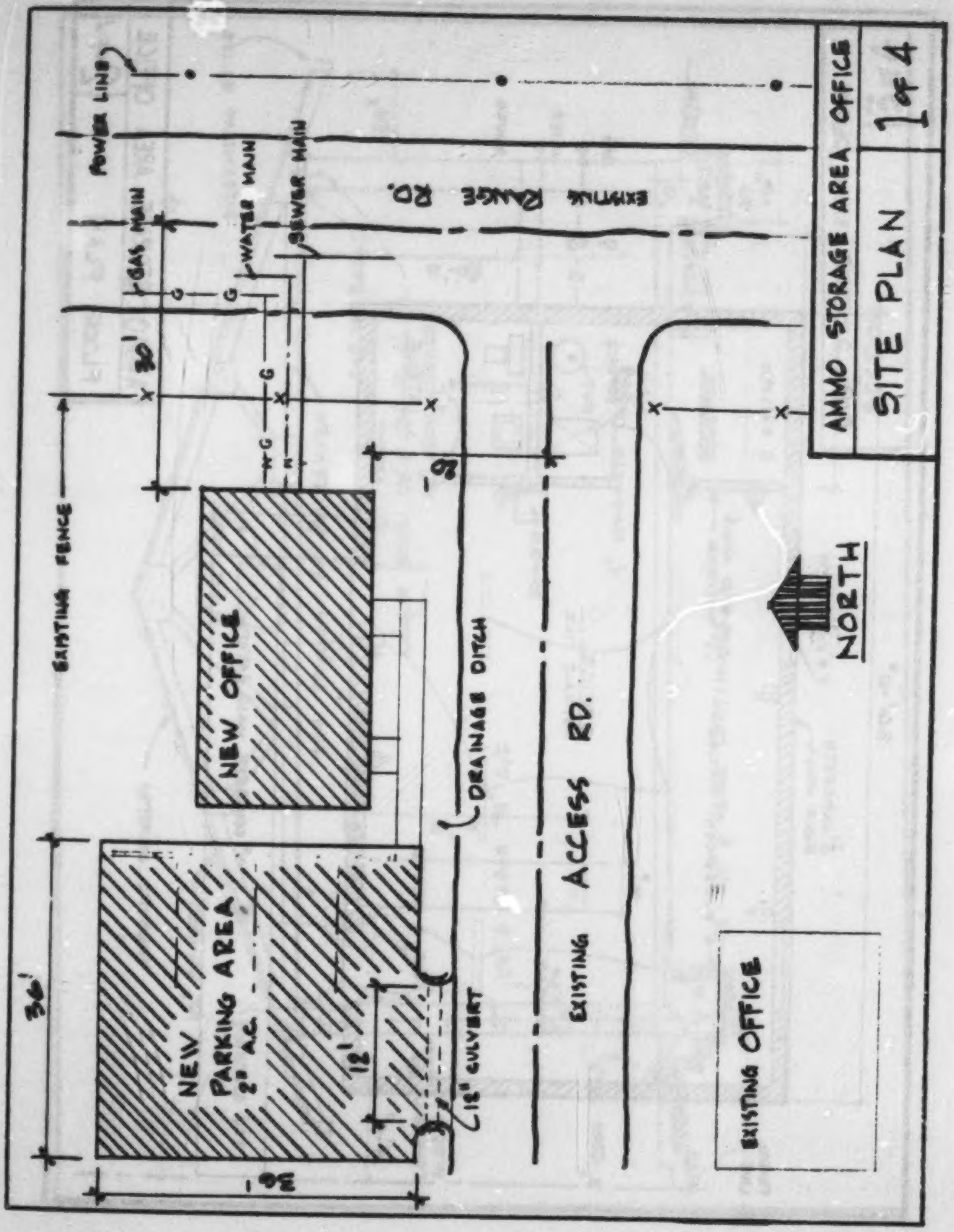
4. Nature of Soil: SC, sandy clay.

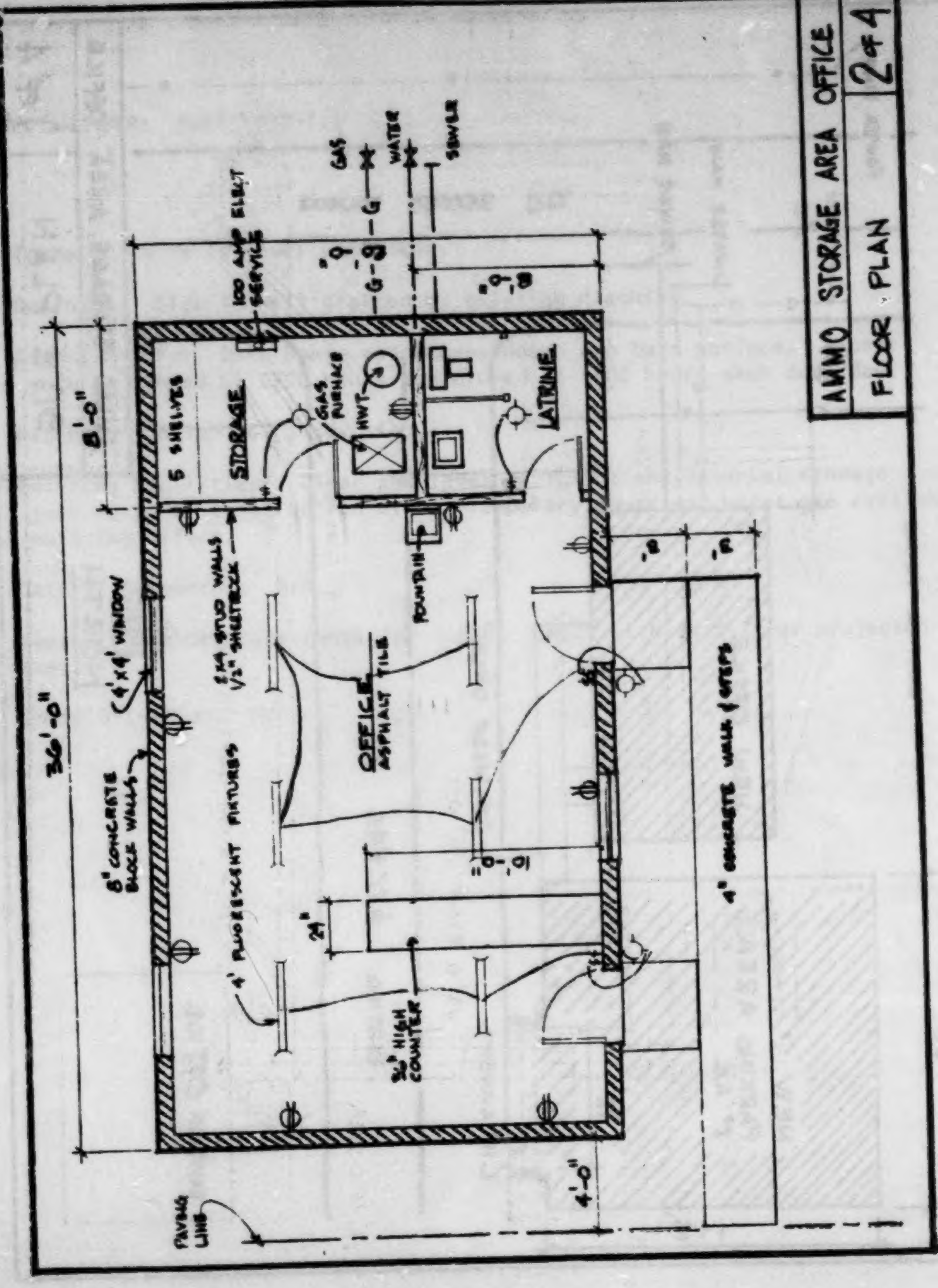
5. Existing Facilities: Clear and level equipment and material storage area just north of construction site. Temporary power and water are available from existing office.

6. Natural Resources: N/A

7. Weather: Temperature range 30° - 50°. Check with Bn S-2 for projected forecast.

8. Enemy Situation: N/A

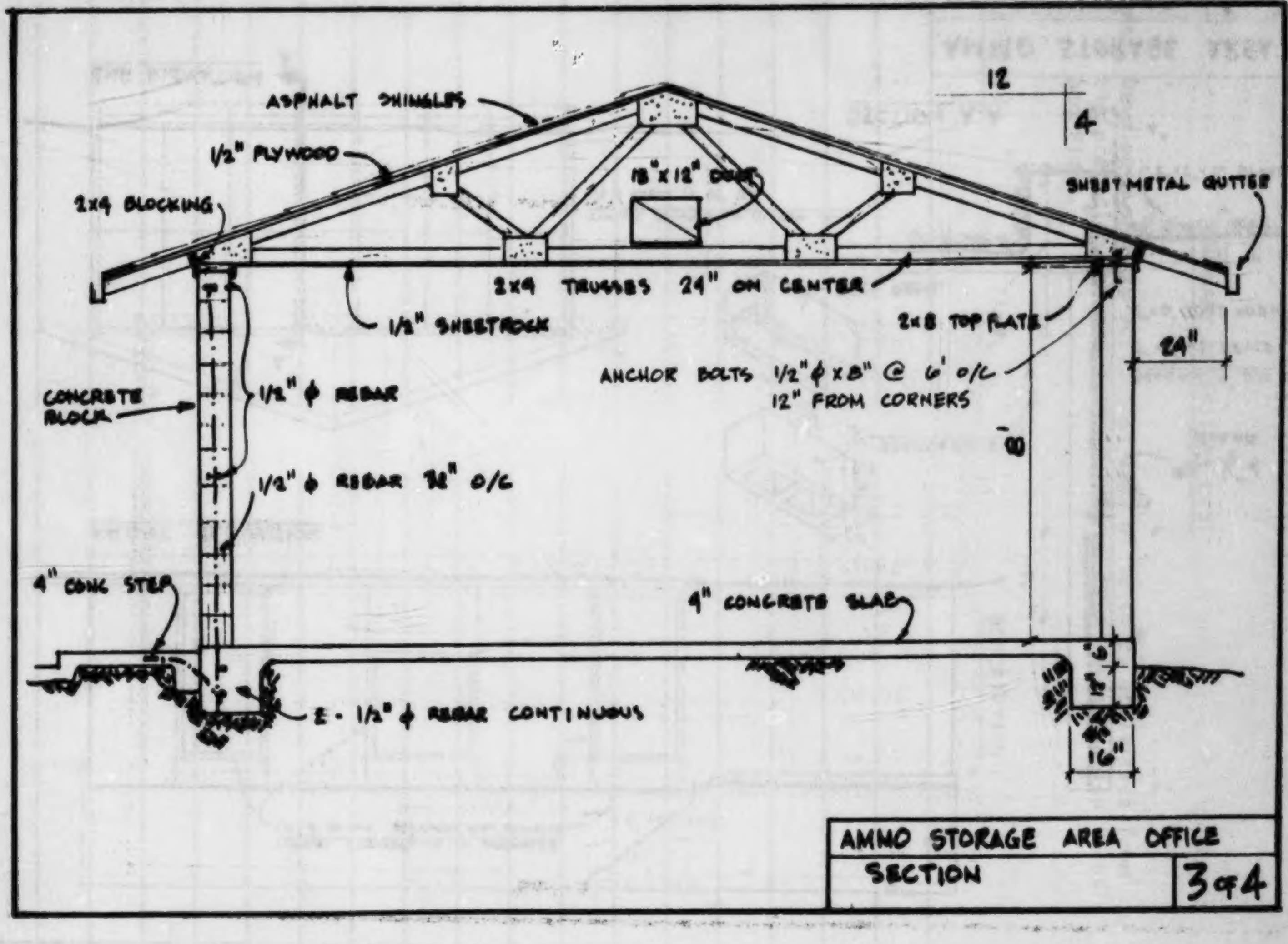

AMMO STORAGE AREA OFFICE
SITE PLAN
1 of 4
POWER LINE
GAS MAIN
WATER MAIN
SEWER MAIN
EXISTING RANGE RD.
EXISTING FENCE
30'
16'
G
NEW OFFICE
DRAINAGE DITCH
EXISTING ACCESS RD.
NEW PARKING AREA 2" A.C.
36'
36'
12'
18" CULVERT
EXISTING OFFICE
NORTH


36'-0"
8'-0"
8" CONCRETE BLOCK WALLS
(4'x4') WINDOW
4' FLUORESCENT FIXTURES
36" HIGH COUNTER
24"
10'-0"
OFFICE
ASPHALT TILE
2x4 STUD WALLS
1/2" SHEETROCK
FOUNTAIN
5 SHELVES
STORAGE
GAS FURNACE
HWT
LATRINE
100 AMP ELECT SERVICE
GAS
WATER
SEWER
6'-0"
8'-6"
8'
8'
4" CONCRETE WALK & STEPS
PAVING LINE
4'-0"

AMMO STORAGE AREA OFFICE

FLOOR PLAN

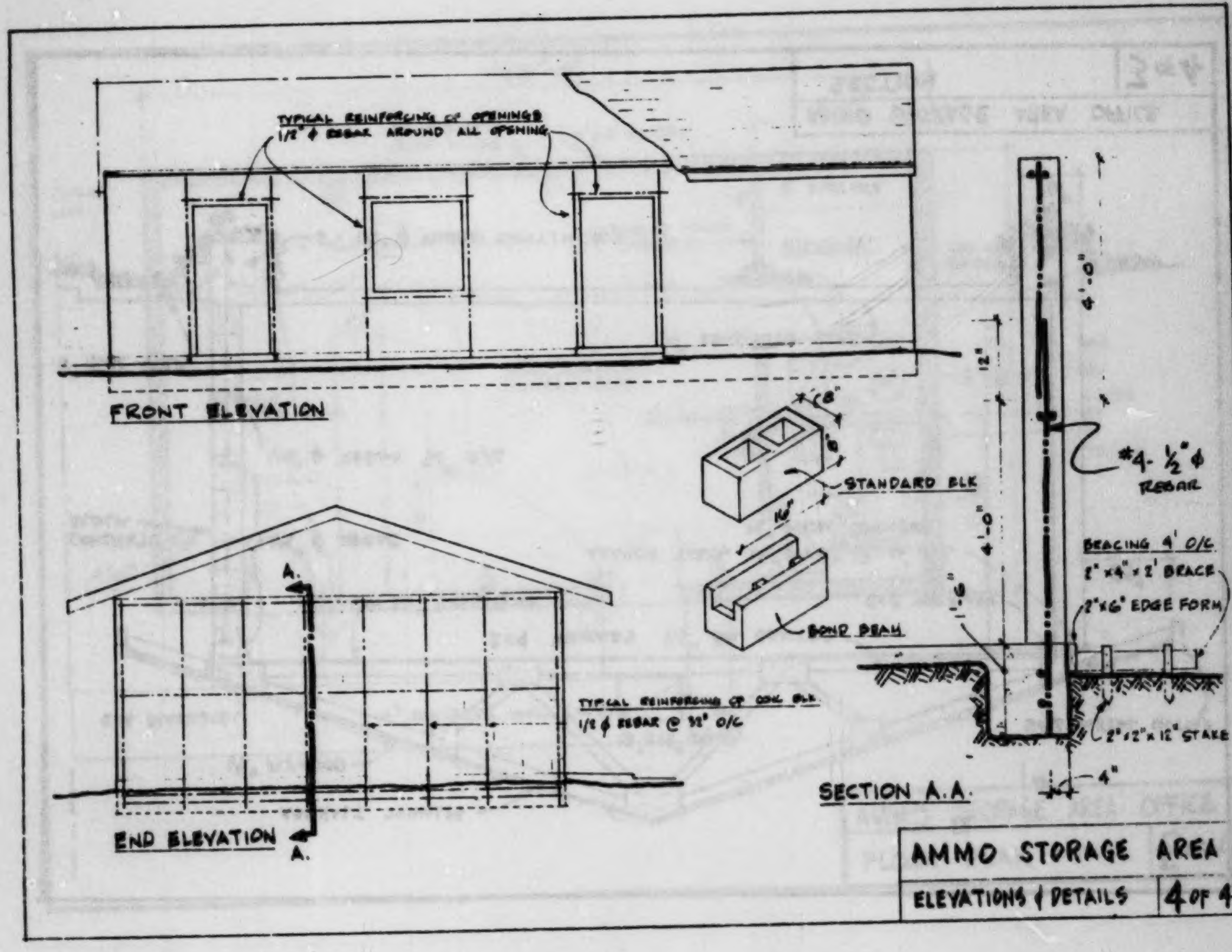
2 of 4


ASPHALT SHINGLES
1/2" PLYWOOD
2x4 BLOCKING
18" x 12" DUCT
12
4
SHEET METAL GUTTER
2x4 TRUSSES 24" ON CENTER
1/2" SHEETROCK
2x8 TOP PLATE
24"
ANCHOR BOLTS 1/2" ϕ x 8" @ 6' O/C
12" FROM CORNERS
CONCRETE BLOCK
1/2" ϕ REBAR
1/2" ϕ REBAR 32" O/C
8'
4" CONC STEP
4" CONCRETE SLAB
2 - 1/2" ϕ REBAR CONTINUOUS
16"

AMMO STORAGE AREA OFFICE

SECTION

3 of 4


TYPICAL REINFORCING OF OPENINGS
1/2" ϕ REBAR AROUND ALL OPENING
FRONT ELEVATION
END ELEVATION
A.
A.
TYPICAL REINFORCING OF CONC BLK.
1/2 ϕ REBAR @ 32" O/C
8"
8"
16"
STANDARD BLK
BOND BEAM
12"
4'-0"
4'-0"
1'-6"
*4- 1/2" ϕ
REBAR
BRACING 4' O/C
2" x4" x 2' BRACE
2"x6" EDGE FORM
2"x2"x 12" STAKE
4"
SECTION A.A.
AMMO STORAGE AREA
ELEVATIONS & DETAILS
4 OF 4

STUDENT PRACTICAL EXERCISE I

SUMMARY ACTIVITIES LIST

Requirement: Develop a summary activities list of 10 to 20 activities from the preceding Construction Directive, Site Investigation Notes and Plans.

ACTIVITY	DESCRIPTION

SELF-EVALUATION QUESTIONS ACTIVITY LIST DEVELOPMENT - 1

1. When listing activities which of the following should not be considered?

   a. Plans
   b. Men
   c. Degree of detail
   d. Component parts

2. An activity on the Activity List consists of a short descriptive phrase and a comprehensive description. Explain why the comprehensive descripti is needed:

   ____

   ____

   ____

   ____

   ____

   ____

3. A definable activity is an activity which has a specific beginning and a specific end.

   TRUE FALSE

4. What is the difference between the activities list and the operational p

SELF-EVALUATION QUESTION ACTIVITY LIST DEVELOPMENT - II

1. Briefly explain why the development of an Activity List is so difficult for many managers.

2. Who do you feel should prepare the Activity List for a project? Why?

3. When checking an Activity List for a project what are two major evaluation points to remember?

ANSWERS TO SELF-EVALUATION QUESTIONS - I

1. b men - Resources are ignored when developing the activities list.

2. The description is needed to accurately indicate all the subtasks that compose the activity.

3. TRUE

4. The activities list contains the specific tasks involved in accomplishing the project while the operational plan contains administrative and logistic information in support of the project.

EXAMPLE PROBLEM SOLUTION

ACTIVITY	DESCRIPTION
1. Dig Trench #1	Trench will be dug to permit installation of culvert. The earth removed will be used to backfill.
2. Dig Trench #2	Trench will be dug to permit installation of culvert. The earth removed will be used to backfill.
3. Assembly #1	The culvert is corrugated sheet metal. The culvert comes in 10-foot sections and must be assembled to the required length.
4. Assemble #2	Same as #1, except that the assembly area is small and only one culvert at a time can be assembled.
5. Install Culvert #1	Installation will be done by hand.
6. Install Culvert #2	Same as #1.
7. Backfill #1	Backfill using shovels and pneumatic tampers to desired compaction.
8. Backfill #2	Same as #1.

Although no two activities list will be identical, for this project it must include as a minimum the above 8 activities. If your list included more or less activities just remember that the activities list must include all the steps necesary to complete the mission as stated.

pages tightly bound

A SOLUTION FOR STUDENT PRACTICAL EXERCISE I

ACTIVITY	DESCRIPTION
1. SITE PREPARATION	Clear site, compact subbase and lay out buildings and park area IAW specs and drawin
2. CONSTRUCT FORMS	To include excavation of footings and placement of reinforcing steel IAW specs and drawings.
3. CONNECT UTILITIES	Installation of all under slab utility pipes IAW drawings to include sewer, gas, electric and water.
4. PLACE CONCRETE	Place, finish and cure concrete slab to satisfy the compression strength. A float finish will be used on all interior walls.
5. PLACE CONCRETE BLOCKS	Place concrete block walls, reinforcing bars anchor bolts and grout.
6. INSTALL TRUSSES	Install top plate, erect trusses, block and brace.
7. ASSEMBLE TRUSSES	Cut, assemble and stack trusses on site.
8. PRECUT FRAME WALLS	Cut plates, studs, trimmers, headers, cripples and stack on site.
9. FRAME INTERIOR BUILDING	Measure, cut and install wood framing includ firestops, cripples, headers and door frames
10. INSTALL ROOFING	Install plywood decking, roof gutters, downspouts and asphalt shingles.
11. FINISH UTILITIES	To include installing and connecting receptacles, switches, controls and appliances and plumbing fixtures, heating ducts and water lines.
12. FINISH CARPENTRY	Install baseboards, molding, door and window frames and trim, cabinets and wooden stairs, closets and finish walls.
13. WALK AND STEPS	Layout, construct forms, remove forms, place concrete and finish concrete (broom finish).
14. CONSTRUCT PARK AREA	Same as #1.

NETWORK DEVELOPMENT

LESSON: NETWORK DEVELOPMENT - LOGIC

OBJECTIVE: The student, using TM 5-333 and an activities list, will be able to determine the logical relationships of the given tasks and draw a logic network which represents these conditions.

REFERENCES: TM 5-333, para 2-3 through 2-6.
Programmed Text: Network Development.
Engineer Management Review Problems Student Workbook.

STUDENT NOTES

1. Bar Chart or Gantt Chart.

This is an excellent means of construction planning and control. It is primarily used for small projects and is very easy to use. The bar chart's (Figure 1) advantages are its simplicity, conciseness and ease of preparation. The major fault with this management tool is that the user must have a detailed knowledge of the particular project and of construction techniques. This fault can create a major problem if the project manager is transferred suddenly or gets sick and must be replaced. The replacement is faced with a document in which all the relationships are not readily apparent.

The disadvantages of planning with a bar chart are:

a. The detailed sequence of the activities is not readily apparent.

b. The relationships among the activities are not shown.

c. There is a failure to show which activities are critical or potentially critical to the successful completion of the mission on time.

d. There is a failure to show the precise effect of a delay or failure to complete an activity as planned.

e. In an emergency, may lead to the expediting of activities that are not critical (essential).

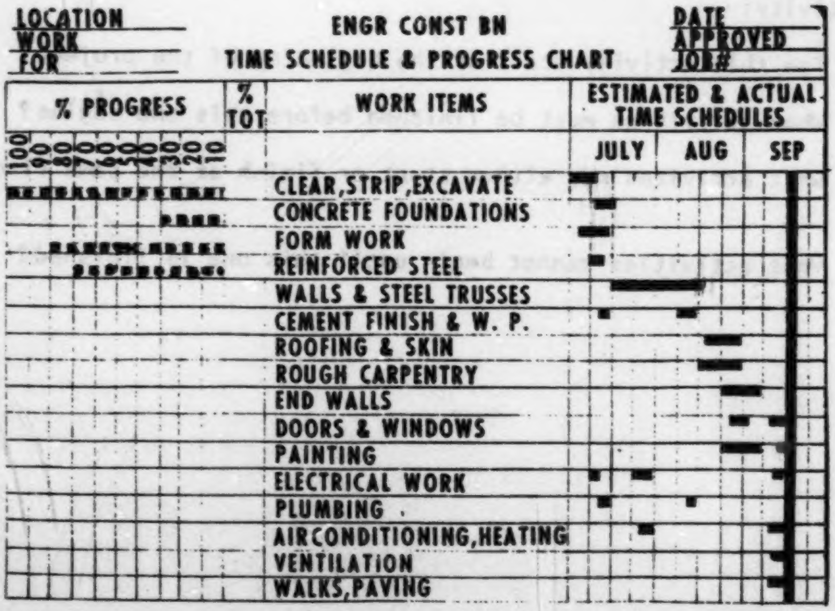


FIGURE 1.

2. Critical Path Method (CPM).

The Critical Path Method (CPM) is a planning and control technique whic overcomes the disadvantages of the bar chart and provides an accurate, time and easily understood picture of the project. A complete history and discussion of CPM can be found in the references listed in the bibliography.

CPM provides the manager with a vast increase in information on the pro compared to the bar chart. This information means that it is easier to pla schedule and control the project.

3. Logic Diagram.

The logic diagram is one of the most important aspects of the Critical Method. The project is actually being constructed mentally and on paper as the relationships between the activities are determined. The result is a s shot of the project. Both the military and the civilian construction indus recognize that some of the major benefits obtained from the development of diagram are the problems that are eliminated and never arise during the con struction phase of the project.

4. The Logic Network.

From the activities list, determine the logical relationships between t activities. To accomplish this the following questions should be asked for each activity:

a. Can this activity start at the beginning of the project?

b. What activities must be finished before this one begins?

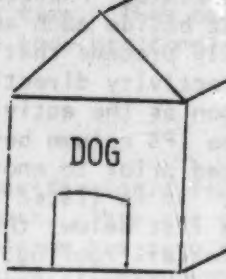
c. What activites may either start or finish at the same time this one does?

d. What activities cannot begin until this one is finished?

LEAD-THROUGH PRACTICAL EXERCISE

ACTIVITIES

1. **Frame Walls**
2. **Build Floor**
3. **Install Roofing**
4. **Install Siding**
5. **Install Trusses**
6. **Prefab Trusses**



After developing the activities list, one should number the activities. This makes it easier to refer to specific activities. Next, one must determine the logical relationships among the activities. One way to accomplish this is to develop an "IMMEDIATELY PRECEDED BY" (IPB) column next to the activities list. To do this, list beside each activity the numbers of all of the other activities which immediately precede that activity. The activities in this column are those that the activity directly depends on. In the example below, "frame walls can begin as soon as the activity "build floor" is finished. Thus, "build walls is listed in the IPB column beside "frame walls." Just because an activity must be completed prior to another one, however, it is not necessarily listed in the IPB column. It is listed there only if it immediately precedes it. For example, in the list below, the activity "build floor" must be completed before the activity "install roofing." However, there are several activities such as "frame walls" and "install trusses" which must be accomplished between the time the floor is built and the roof is installed. Thus, "install roofing" is not said to depend directly on "build floor." "Build floor" is not included in the IPB column for the activity "install roofing." See the example below for a sample activity list with a correct IPB column.

EXAMPLE:

ACTIVITY LIST	IMMEDIATELY PRECEDED BY (IPB)
1. Frame Walls	2
2. Build Floor	NONE
3. Install Roofing	5
4. Install Siding	1
5. Install Trusses	1,6
6. Prefab Trusses	NONE

After developing the IPB column it is necessary to show the logical relationships among the activities with a LOGIC NETWORK DIAGRAM. Three symbols are used to draw the diagram:

ACTIVITY ARROW

Each activity is represented by a solid arrow. The lengt of the arrow is not related to the duration of the activi The tail of the arrow represents the beginning of the activity. The head of the arrow represents completion of the activity.

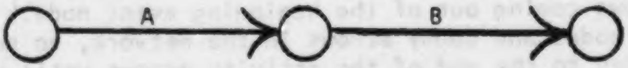
EVENT NODE

An event is the instant when an activity is started or completed. Events are represented by circles called nodes. They do not consume time. They occur when all the activities entering the node are completed.

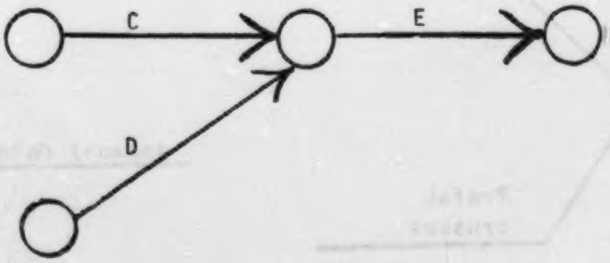
DUMMY ARROW

Dummy arrows are used to transfer logic from one event node to another in the network. They are represented by broken arrows. A dummy arrow has zero duration and does not represent an activity. These symbols are used to represent the relationships among the activities.

Activity A must be completed before Activity B can begin.

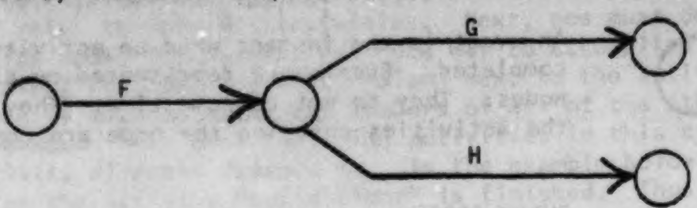


Activity C and D must both be completed before E can begin.

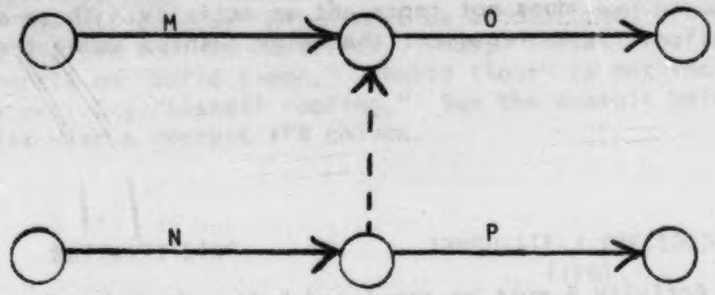


pages tightly bound

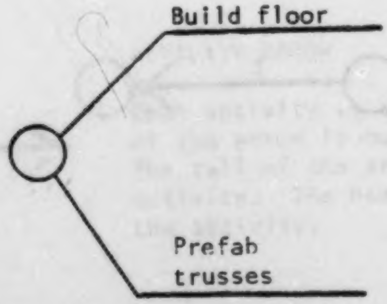
Activity F must be completed before Activities G and H can begi



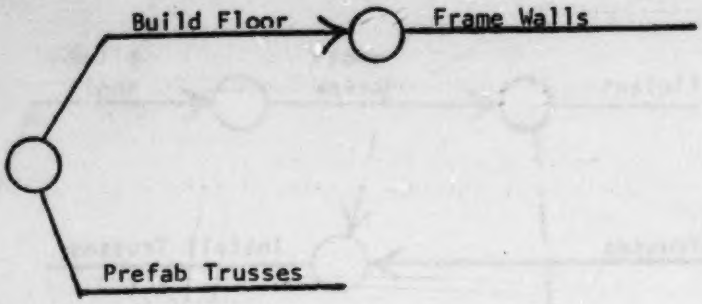
Activity M must be completed before Activity P can begin.
Activities M and N must both be completed before Activity O can begin.



Every logic network diagram starts with one event node. That node is called the "beginning event node." Look at the activity list and the IPB column (page 38) to see which activities do not depend on any of the other activities. These activities should be represented with activity arrows coming out of the beginning event node. To avoid having extra nodes and dummy arrows in the network, do not add arrowheads and nodes to the end of the activity arrows until you discover where they are going.

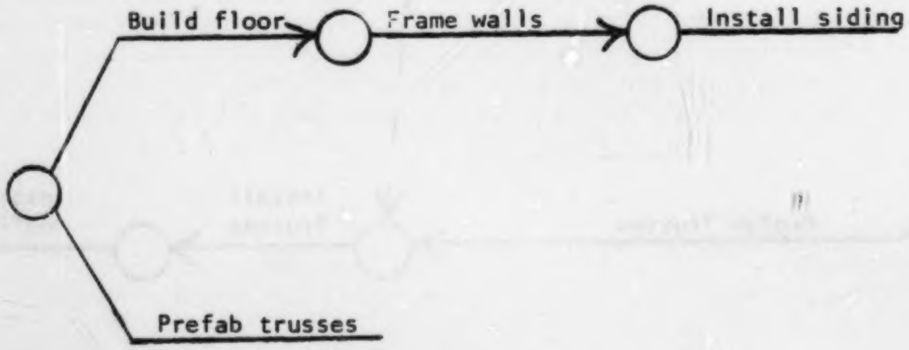


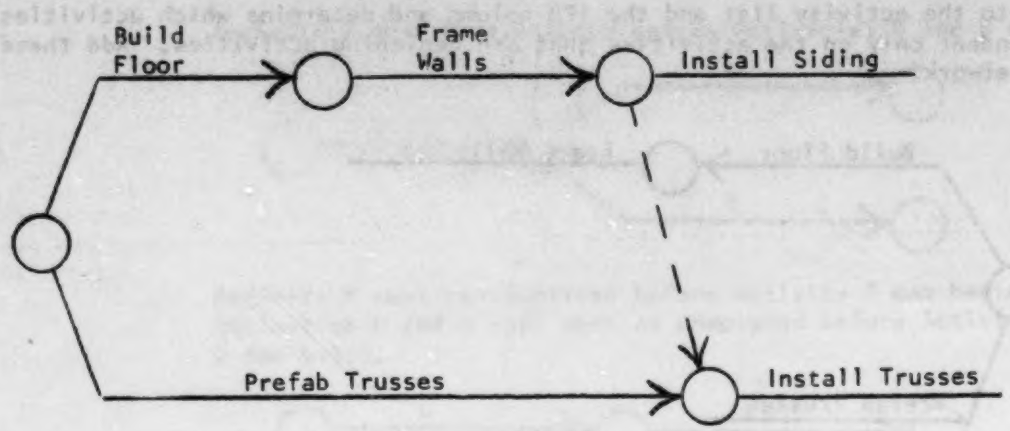
Go back to the activity list and the IPB column and determine which activities are dependent only on the activities that are beginning activities. Add these to the network.

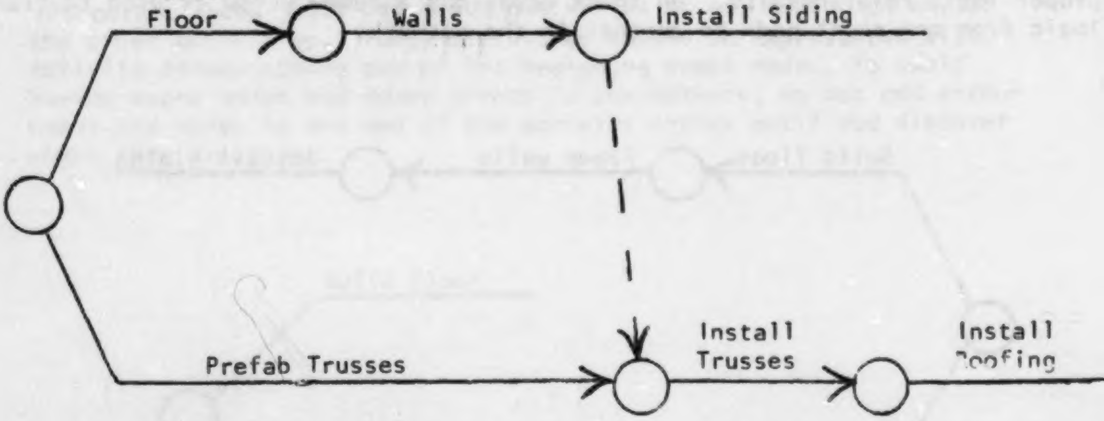

Build Floor
Frame Walls
Prefab Trusses

Notice that only after discovering where the activity arrow representing "Build Floor" was going was the arrowhead added.

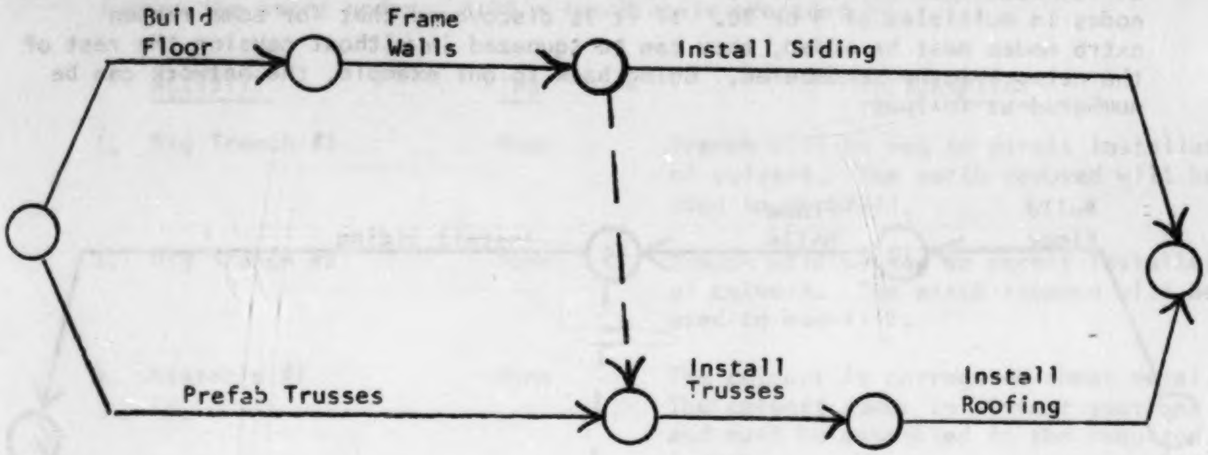
Continue by going back to the activity list and the IPB column and identifying activities whose immediate predecessors have all been added to the network previously. Add these to the network. Continue the procedure until all the activities and relationships have been shown. Occasions arise where it is physically impossible to connect the arrow's head to tail and maintain all the proper logic relationships. On these occasions a dummy arrow is used to transfer logic from one event node to another in the network.


Build floor
Frame walls
Install siding
Prefab trusses


Build Floor
Frame Walls
Install Siding
Prefab Trusses
Install Trusses

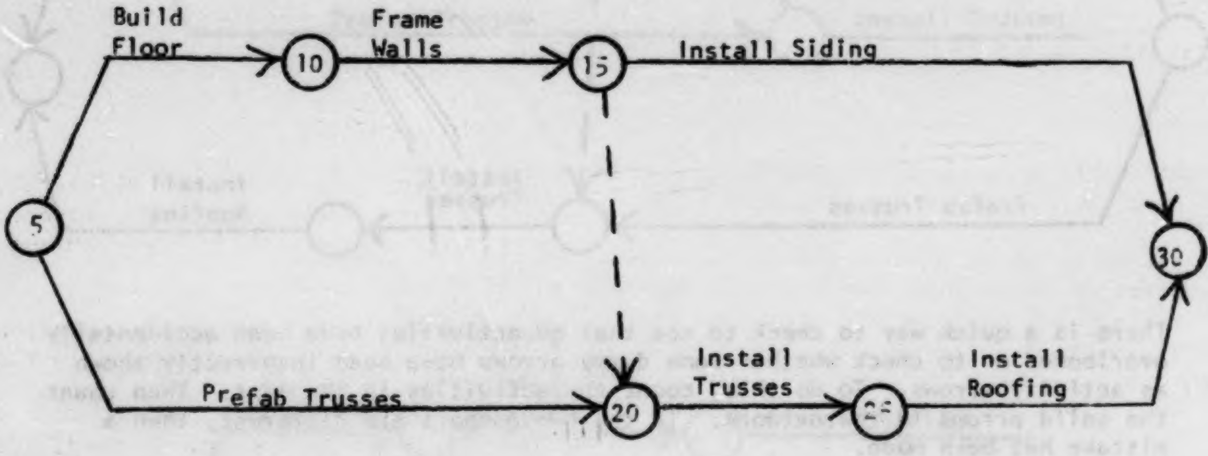

Build Floor
Frame Walls
Install Siding
Prefab Trusses
Install Trusses
Install Roofing

Just like the project had one beginning event node, it should also have one ending event node. All of the activities that do not have any activities depending on them must end at the ending event node.

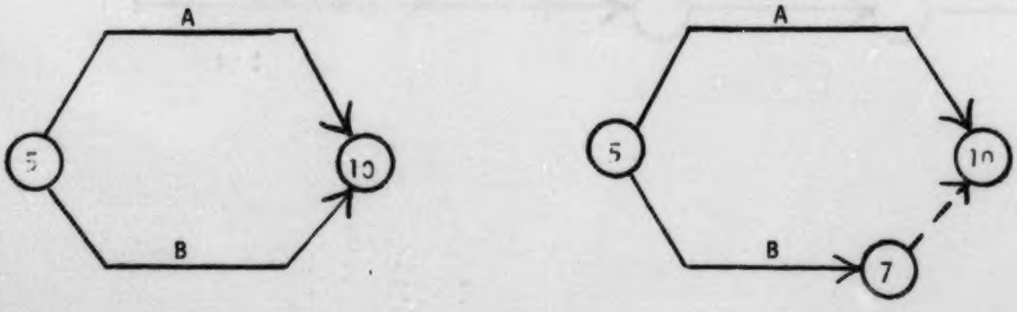

Build Floor
Frame Walls
Install Siding
Prefab Trusses
Install Trusses
Install Roofing

There is a quick way to check to see that no activities have been accidentally overlooked or to check whether some dummy arrows have been incorrectly shown as activity arrows. To do this, count the activities in the list. Then count the solid arrows in the network. If the two numbers are different, then a mistake has been made.

After the network has been drawn, the event nodes must be numbered. This is done because later the activities will be referred to by their head and tail numbers rather than by their names. There are only two simple rules to remember when numbering the event nodes. 1) The same number cannot be used more than one time in the network. 2) Each activity must have a larger number at its head than at its tail. A helpful common practice is to number the nodes in multiples of 5 or 10. If it is discovered that for some reason extra nodes must be added, they can be squeezed in without causing the rest of the network to be renumbered. Going back to our example, the network can be numbered as follows:



As mentioned earlier, activities can be referred to by their head and tail numbers. Therefore, it is important that no two activity arrows have both the same head and tail numbers. When two activities start at the same node and both go to the same node, then an extra node and dummy arrow must be added. This will not change any of the logical relationships, but it will eliminate the problem of having two activities with the same head and tail numbers.



Incorrect Correct

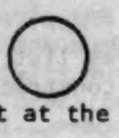
STUDENT PRACTICAL EXERCISE I

Using the activities list below and the conditions stated in the preliminary planning section, construct a logic network for the Two Culvert Problem and number the event nodes. *IPB = Immediately preceded by.

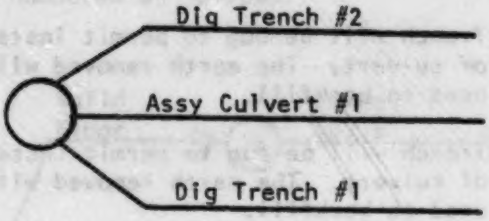
ACTIVITY	*IPB	DESCRIPTION
1. Dig Trench #1	None	Trench will be dug to permit installation of culvert. The earth removed will be used to backfill.
2. Dig Trench #2	None	Trench will be dug to permit installation of culvert. The earth removed will be used to backfill.
3. Assemble #1	None	The culvert is corrugated sheet metal. The culvert comes in 10-foot sections and must be assembled to the required length.
4. Assemble #2	3	Same as #1, except that the assembly area is small and only one culvert at a time can be assembled.
5. Install Culvert #1	1,3	Installation will be done by hand.
6. Install Culvert #2	2,4	Same as #1.
7. Backfill #1	5	Backfill using shovels and pneumatic tampers to desired compaction.
8. Backfill #2	6	Same as #1.

DISCUSSION OF SOLUTION TO PRACTICAL EXERCISE I

1. Start by drawing the beginning event node.



2. Next, determine those activities that can start at the beginning of the projec

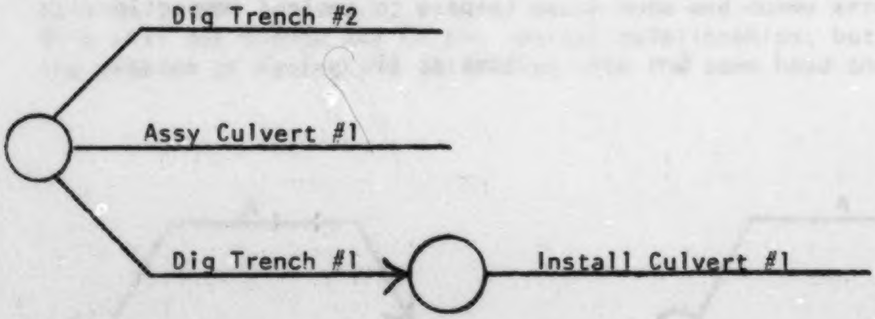

Dig Trench #2
Assy Culvert #1
Dig Trench #1

REMEMBER: It is recommended that the head of the arrow be left off until after you are sure of where the activity arrow will end.

3. Determine which activities can start after the ones previously drawn have been completed.

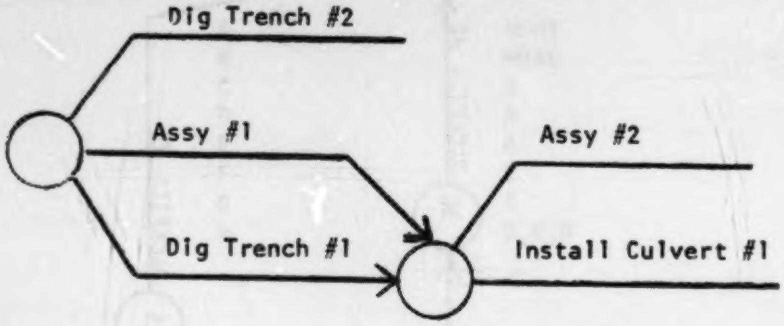
a. End the activity.

b. Add an event node to show the point in time where one activity ends and the other begins.

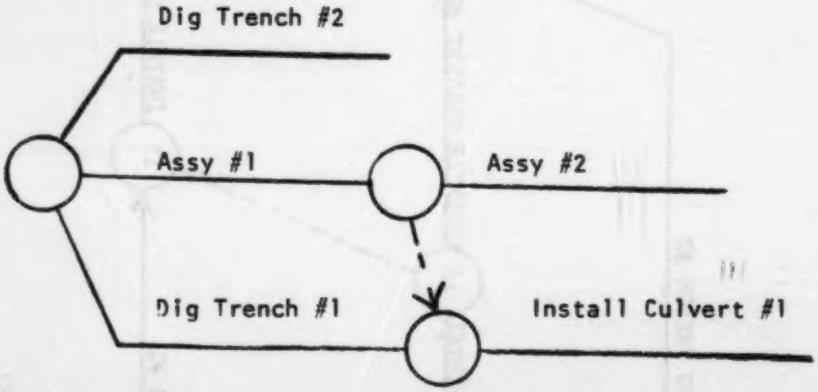

Dig Trench #2
Assy Culvert #1
Dig Trench #1
Install Culvert #1

4. Continue this procedure for the other activities.

Notice that the first inclination is to draw the logic as follows:

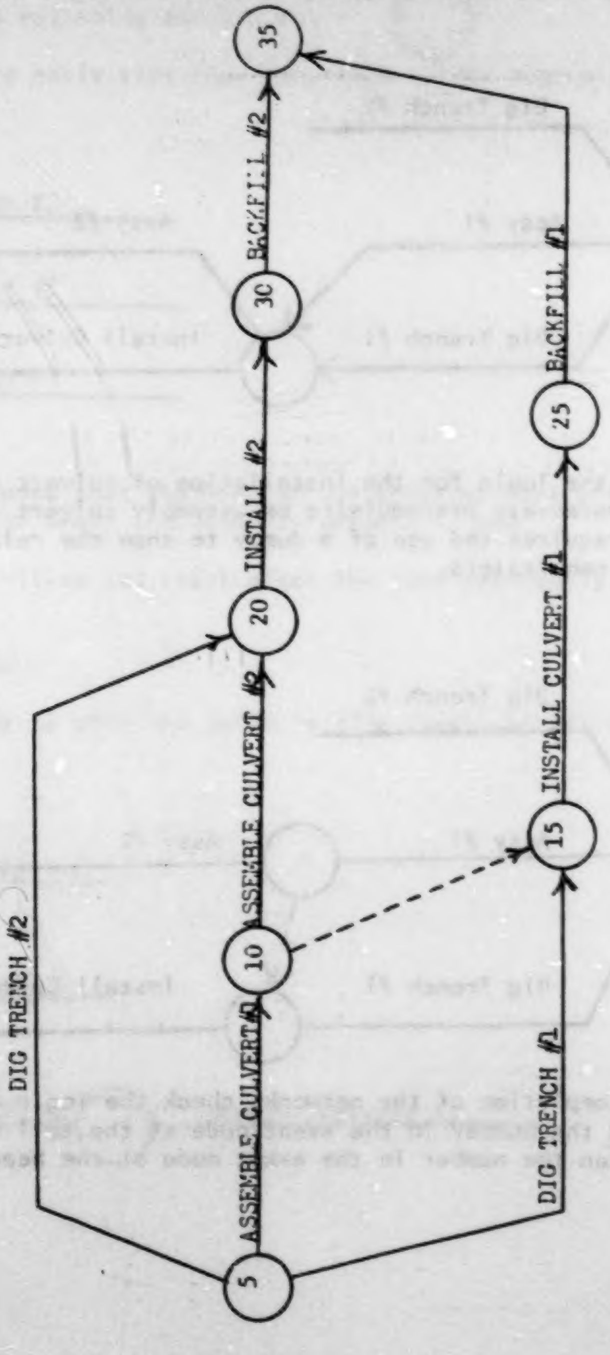

Dig Trench #2
Assy #1
Assy #2
Dig Trench #1
Install Culvert #1

This satisfies the logic for the installation of culvert #1 but places an additional, unnecessary prerequisite on assembly culvert #2. The correct logic diagram requires the use of a dummy to show the relationship without any additional constraints.


Dig Trench #2
Assy #1
Assy #2
Dig Trench #1
Install Culvert #1

5. After the completion of the network, check the logic and number the network. REMEMBER the number in the event node at the tail of the activity must be less than the number in the event node at the head of the activity.

SOLUTION TO PRACTICAL EXERCISE I, PAGE 45


5
ASSEMBLE CULVERT #1
10
ASSEMBLE CULVERT #2
20
INSTALL #2
30
BACKFILL #2
35
DIG TRENCH #2
DIG TRENCH #1
15
INSTALL CULVERT #1
25
BACKFILL #1

STUDENT PRACTICAL EXERCISE II

ACTIVITIES LIST

ACTIVITY	IPB
A	NONE
B	NONE
C	B
D	A
E	A
F	E
G	C
H	D,F,G

REQUIREMENT: Prepare a CPM logic network using the above activities list and number the event nodes.

STUDENT PRACTICAL EXERCISE III

BUNKER PROJECT ACTIVITIES LIST

ACTIVITY	IPB	DESCRIPTION
A Site Preparation	None	Excavate and level site for placi wall panels.
B Prefab Wall Panels	None	Frame wall panels, install 1" sheathing over wall frame.
C Place Wall	A,B	Erect the (4) wall panels, connect the corners.
D Install Floor	C	Install 2" x 6" floor joist over s plate of wall panels and fasten. Install 1" flooring over floor joi
E Finish Interior	D	Cut and install firing table and b
F Place Sand Bags	C	Fill, stack and tamp sandbags arou bunker.
G Install RPG Fence	None	Dig fence post holes, place posts, backfill posts, string chain link
H Prefab Roof	None	Frame roof panel, install corrugat sheetmetal over frame.
I Place Roof	H,C	Install roof over bunker and conne to the post.

REQUIREMENT: Prepare a CPM Logic Network using the above activity list and number the event nodes.

STUDENT PRACTICAL EXERCISE IV

ACTIVITIES LIST

ACTIVITY	IPB
A	None
B	None
C	None
D	A
E	A
F	B,C
G	B,E
H	D
I	G
J	F
K	F
L	I,J
M	J

REQUIREMENT: Prepare a CPM Logic Network using the above activities list and number the event nodes.

STUDENT PRACTICAL EXERCISE V

ACTIVITIES LIST

ACTIVITY	IPB
A	None
B	A
C	A
D	A
E	B,C,D
F	B
G	B
H	D
I	E,F,G

REQUIREMENT: Prepare a CPM Logic Network using the above activities list and number the event nodes.

STUDENT PRACTICAL EXERCISE VI

PURPOSE: To give the student practice in preparing a CPM logic network from a list of activities.

SITUATION:

1. "S" is the last job on the project.
2. "A" follows "O".
3. "M" and "L" can both start after the completion of "P".
4. "H" follows "L".
5. "B" and "E" can be done concurrently, but only after the finish of "M".
6. "B" precedes "O".
7. "R" cannot start until "H" and "M" are completed.
8. "R" precedes "G".
9. "E" must be finished before "G" and "A" can start.
10. "A" and "G" may finish together, and "S" cannot start until they are both done.

REQUIREMENT: Construct a Logic Network Diagram showing only those relationships given above.

STUDENT PRACTICAL EXERCISE VII

OBJECTIVE: To develop self-confidence in designing a CPM Logic Network.

REQUIREMENTS: Using the methods and techniques presented in the Project Planning Class:

1. Prepare a Logic Network using the following activities list.
2. Number the event nodes.
3. Add the additional activities or relationships to the network.

A. ACTIVITIES LIST	IPB
A	NONE
B	NONE
C	NONE
D	A
E	A
F	A, B, C
G	D
H	E, F
I	G, H

B. ADD THE ADDITIONAL ACTIVITIES OR RELATIONSHIPS TO THE NETWORK.

ACTIVITY	IPB
J (Added Activity	C
K (Added Activity	A, J
I	also on K
L (Added Activity)	D, L
M (Added Activity)	
G	also on E

Logic Diagram Part A.

Logic Diagram Part B.

STUDENT PRACTICAL EXERCISE VIII

SUMMARY ACTIVITIES LIST T/O BUILDING

ACTIVITY	IPB	DESCRIPTION
A. SITE PREPARATION	NONE	Clear site, compact base and layout building and helipad.
B. FOUNDATION	A	Excavate for footings, erect footings and posts and backfill.
C. GIRDERS	B	Erect girders with scabbing and closer board.
D. PREFAB FLOOR PANELS	NONE	Cut joist and drill bolt holes. Nail 4x9 plywood sheets to joist
E. INSTALL FLOOR PANELS	C,D	Place panels and secure with bolts and closer board.
F. PREFAB WALL PANELS	NONE	Construct wall frames and fasten sheathing to frame.
G. INSTALL WALL PANELS	E,F	Fasten panels together and to floor.
H. PREFAB TRUSSES AND GABLES	NONE	Construct trusses and gables to include gable sheathing.
I. INSTALL TRUSSES AND GABLES	G,H	Fasten trusses and gables to wal panels & nail bracing between trusses.
J. ROOFING	I	Erect purlins, install corrugate sheet metal and fascia board.
K. PREFAB DOORS, WINDOWS, & STAIRS	NONE	Includes all necessary hardware and handrails.
L. INSTALL DOORS, WINDOWS, & STAIRS.	G,K	As per plans.
M. PAINT	J,L	Paint interior and exterior of T/O structure.
N. DITCHING	A	Dig ditch around helipad perimet for membrane anchorage.
O. PLACE MEMBRANE	N,R	Includes anchoring & lap sealin

ACTIVITY	IPB	DESCRIPTION
P. BACKFILL AND COMPACT	0	Backfill & compact anchorage ditch.
Q. SKID PROOFING	0	Apply skid proofing to landing area of helipad.
R. PROCURE MEMBRANE	NONE	Go through S-4.

Prepare a Logic Network (activity on arrow) from the T/O building activities list.

WORK SPACE STUDENT PRACTICAL EXERCISE VIII

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STUDENT PRACTICAL EXERCISE IX

Situation: Using the Summary Activities List, for the Ammunition Storage Area Office (solution to Student Practical Exercise I, page 28).

Requirement: Construct a logic network diagram.

LOGIC PROBLEM I

WEDDING

Having explained to your fiancee the concepts of CPM she decides to use it in planning the wedding. She has no difficulty developing an activities list and the activities relationships to each other; however, she is experiencing problems drawing the logic diagram. The results of her work thus far are shown below.

ACTIVITY	DESCRIPTION	IPB
A	Reserve church	-
B	Notice on church	A
C	Decorate	B,F
D	Bridesmaid	-
E	Choose cakes & decoration	-
F	Caterer notice	E
G	Choose pattern	-
H	Order material	G
I	Sewing	H
J	Fitting	I,D
K	Pressing & cleaning	J
L	Invitation lead	M
M	Posting mail	N
N	Addressing	P,Q
O	Gifts	-
P	Guest list	-
Q	Printer	R
R	Choose invitations	-
S	Rehearsal	C,K,O
T	Wedding	L,S

SPACE TO WORK LOGIC PROBLEM 1

LOGIC PROBLEM 2

ACTIVITY	IPB
A	NONE
B	A,D
C	B,F
D	NONE
E	A,D
F	E,G,I
G	NONE
H	E,G,I
I	NONE
J	I
K	H,J

SPACE TO WORK LOGIC PROBLEM 2

LOGIC PROBLEM 3

ACTIVITY	IPB
R	NONE
S	R
T	R
U	S,T
V	T
W	U,V
X	U
Y	V
Z	W,X,Y

SPACE TO WORK LOGIC PROBLEM 3

LOGIC PROBLEM 4

STAGE PLAY

As a member of G-5 you have been asked to produce a stage play for the local populace. In order to use your time most effectively you plan to use CPM. Below is your activities list and the relationships between activities.

	ACTIVITIES LIST	IPB
A.	Design of scenery	J,G
B.	Tryouts for actors	J,G
C.	Selection of a stage manager	H
D.	Publicity - posters and mail advertisements	B
E.	Selection of a director	H
F.	Initial rehearsals	B
G.	Arrangements for theater	H
H.	Selection of play	NONE
I.	Selection of a business manager	H
J.	Production meeting	C,E,I
K.	Final dress rehearsal	P,Q,R,S
L.	Constructing and painting scenery	A
M.	Sale of tickets	D
N.	Opening night performance	K,O,M
O.	Publicity - Newspaper	D
P.	Advanced rehearsals	F
Q.	Making or renting costumes	A,B
R.	Obtaining props	A
S.	Erection of scenery	L

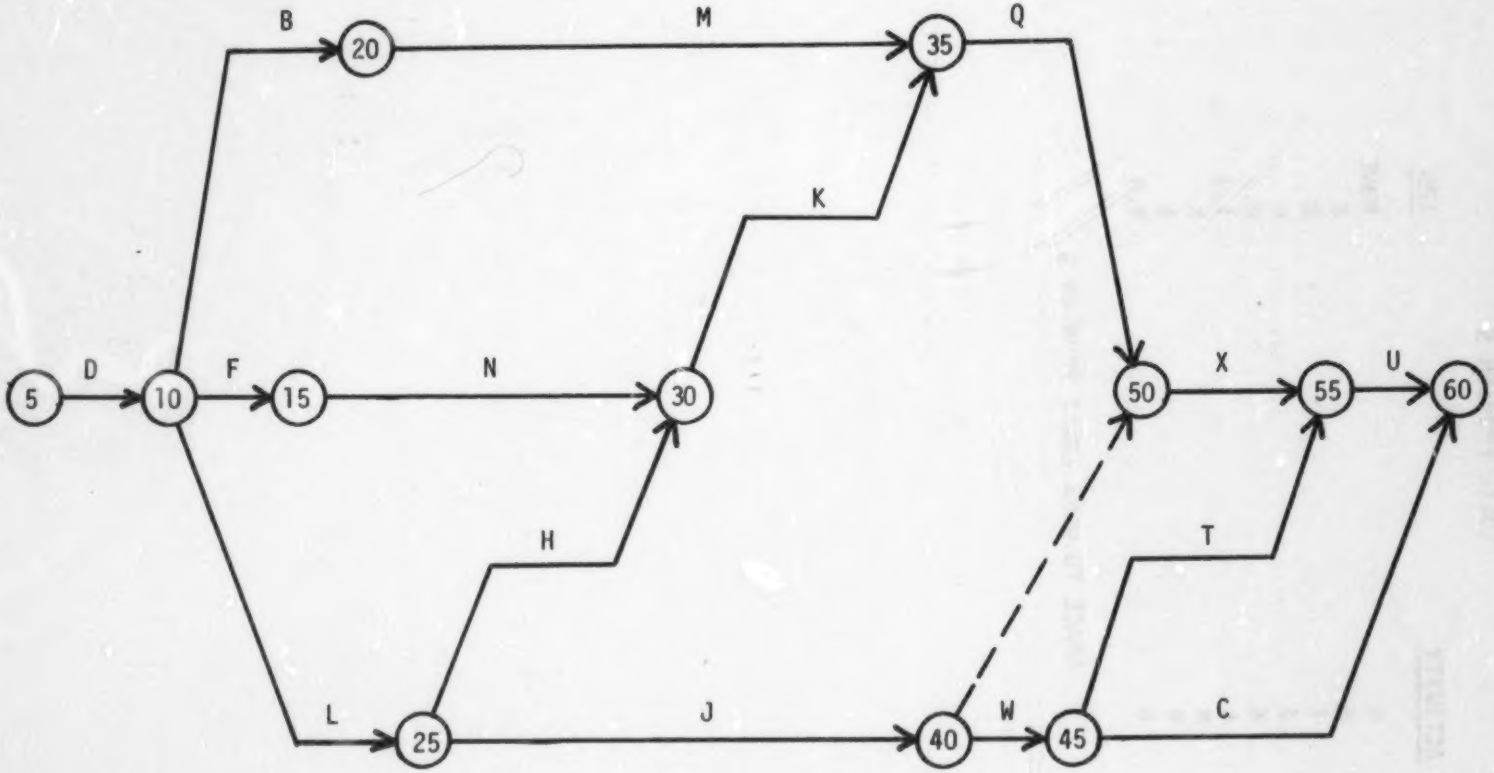
SPACE TO WORK LOGIC PROBLEM 4

LOGIC PROBLEM 5

ACTIVITY	IPB
G	NONE
H	G
I	G
J	G
K	H,I
L	I,J
M	K
N	L
O	M,N

SPACE TO WORK LOGIC PROBLEM 5

LOGIC PROBLEM 6


B
M
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60

In addition to the relationships shown in the network above, without adding unnecessary restraints, show the following additional relationships.

a) Activities H & J cannot start until B is finished.
b) Activity W cannot start until K is finished.

LOGIC PROBLEM 7

SITUATION: You are on the Club Board and have just received word that the President will inspect the post this Thursday and will spend the night.

In honor of the President's visit, a reception has been requested by the Post Commander and you have been detailed to make all the arrangements. In order to manage your time most effectively you plan to use a CPM LOGIC NETWORK.

You have prepared an activities list and the activities relationships to one another. The results of your work are shown below.

REQUIREMENTS: Using the methods and techniques presented in the Engineer Management block of instruction:

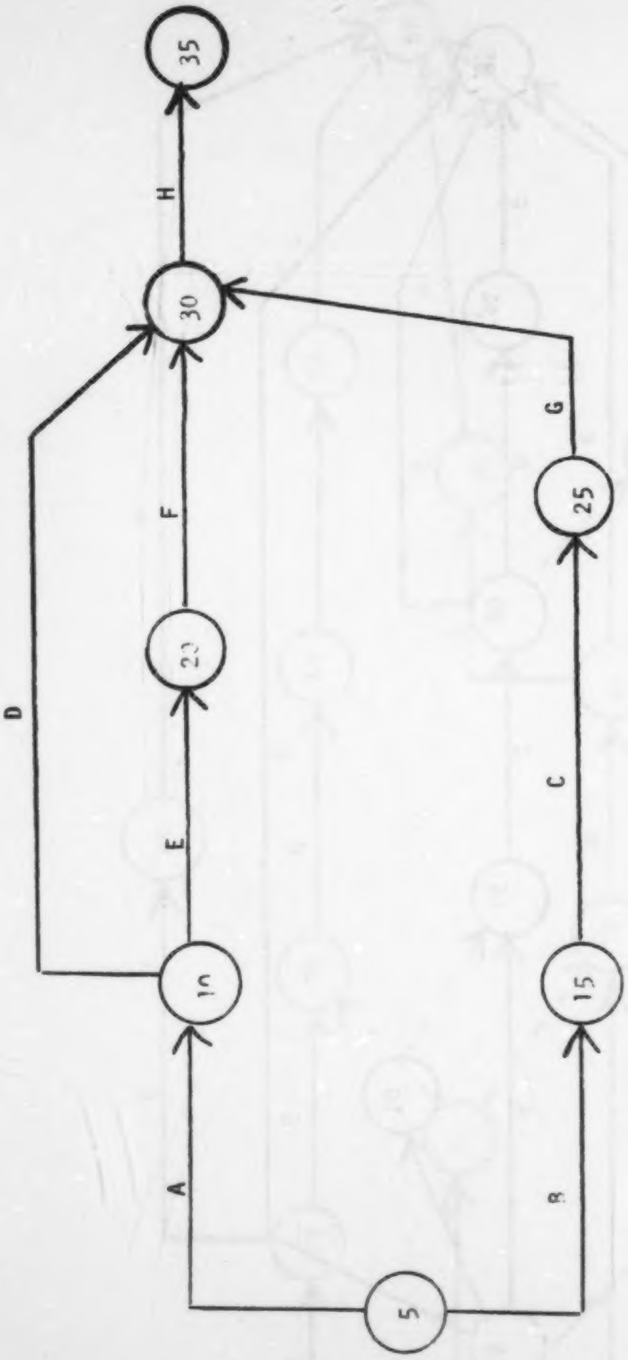
a) Prepare the CPM LOGIC NETWORK showing only those relationships given. DO NOT SHOW ANY ADDITIONAL RESTRAINTS.

b) Number the event nodes.

ACTIVITIES LIST	IPB
A. Arrange time and place for reception	NONE
B. Set motif	NONE
C. Send out invitations	A,B
D. Hire caterer	E
E. Decide on menu	A,B
F. Set out food	D,K
G. Decide on music	A,B
H. Hire musicians	G
I. Arrange for musician's rehearsal	H,P
J. Order decorations	A,B
K. Put up decorations	J,P
L. Arrange for clean-up crew	E,J
M. Have reception	L,I,F
N. Clean-up	M
O. Set seating arrangement	C
P. Prepare reception hall	O

SPACE TO WORK LOGIC PROBLEM 7

SOLUTION: PE II, PAGE 49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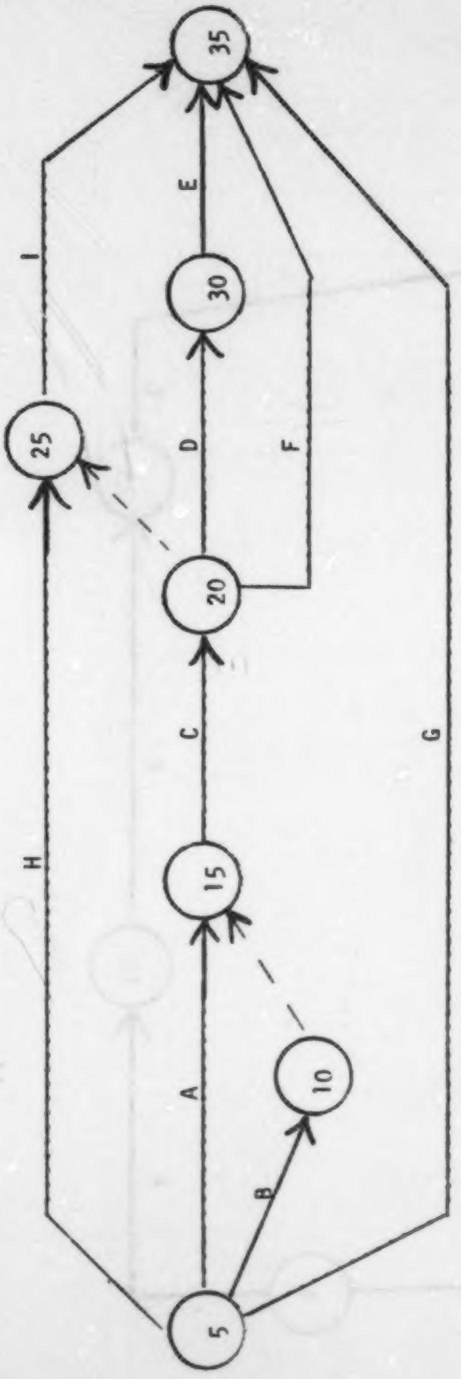
SOLUTION PE III, PAGE 50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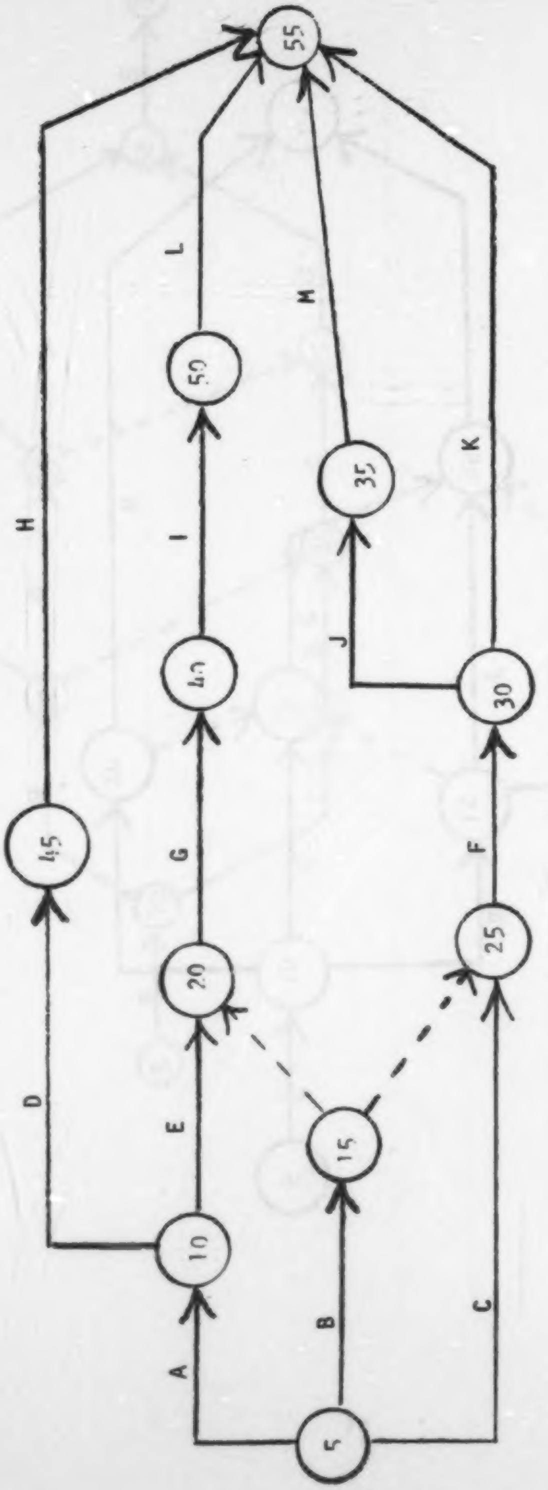
SOLUTION PE IV, PAGE 51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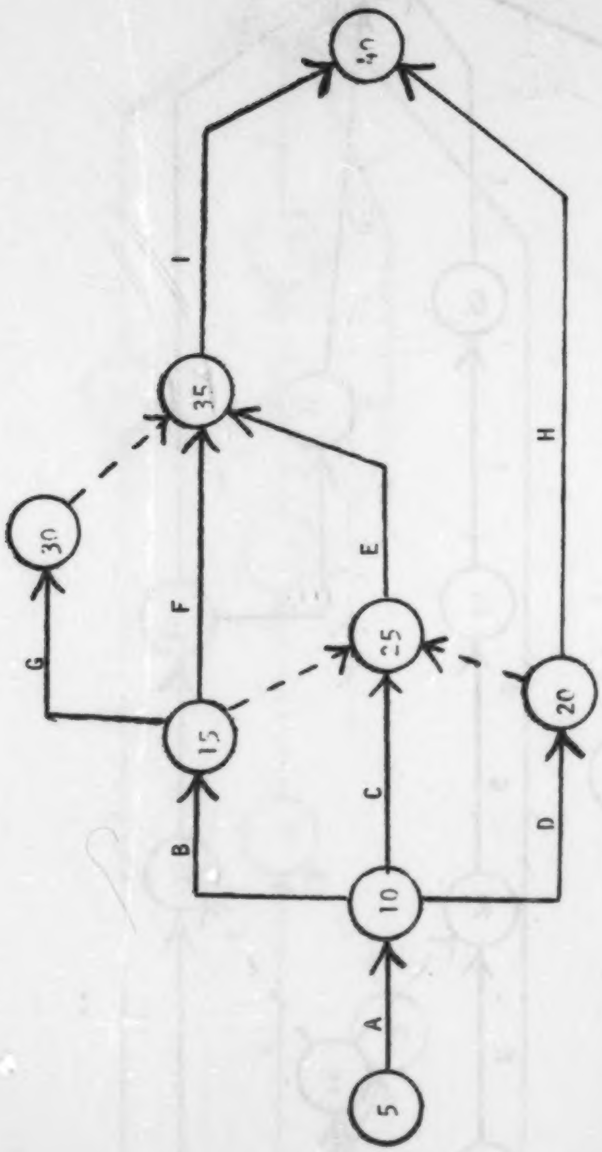
SOLUTION: PE V, PAGE 52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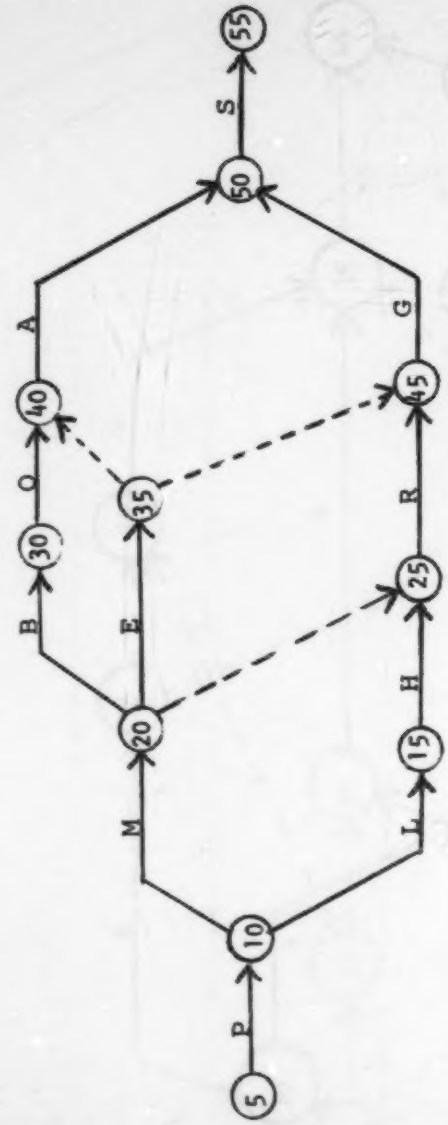
SOLUTION: PE VI, PAGE 53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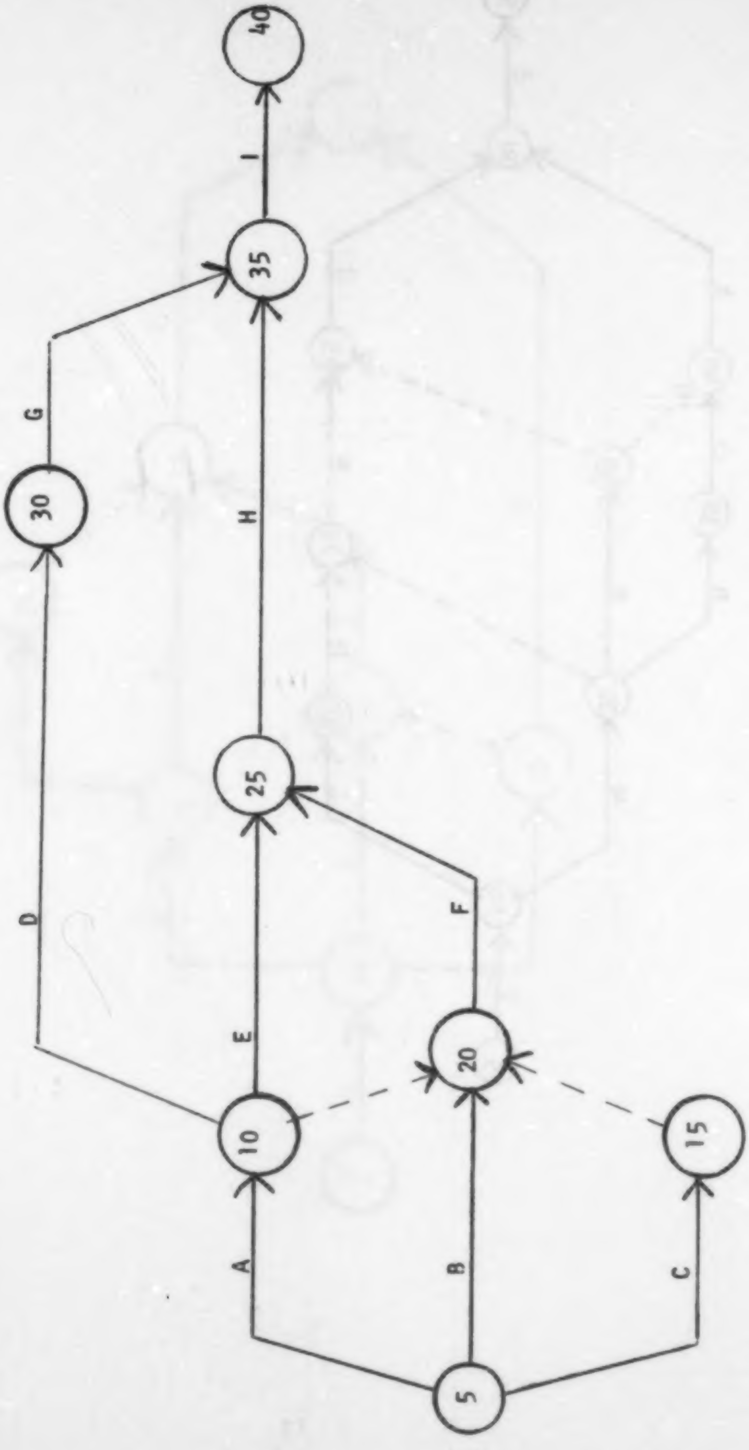
SOLUTION: PE VII, PART A, PAGE 54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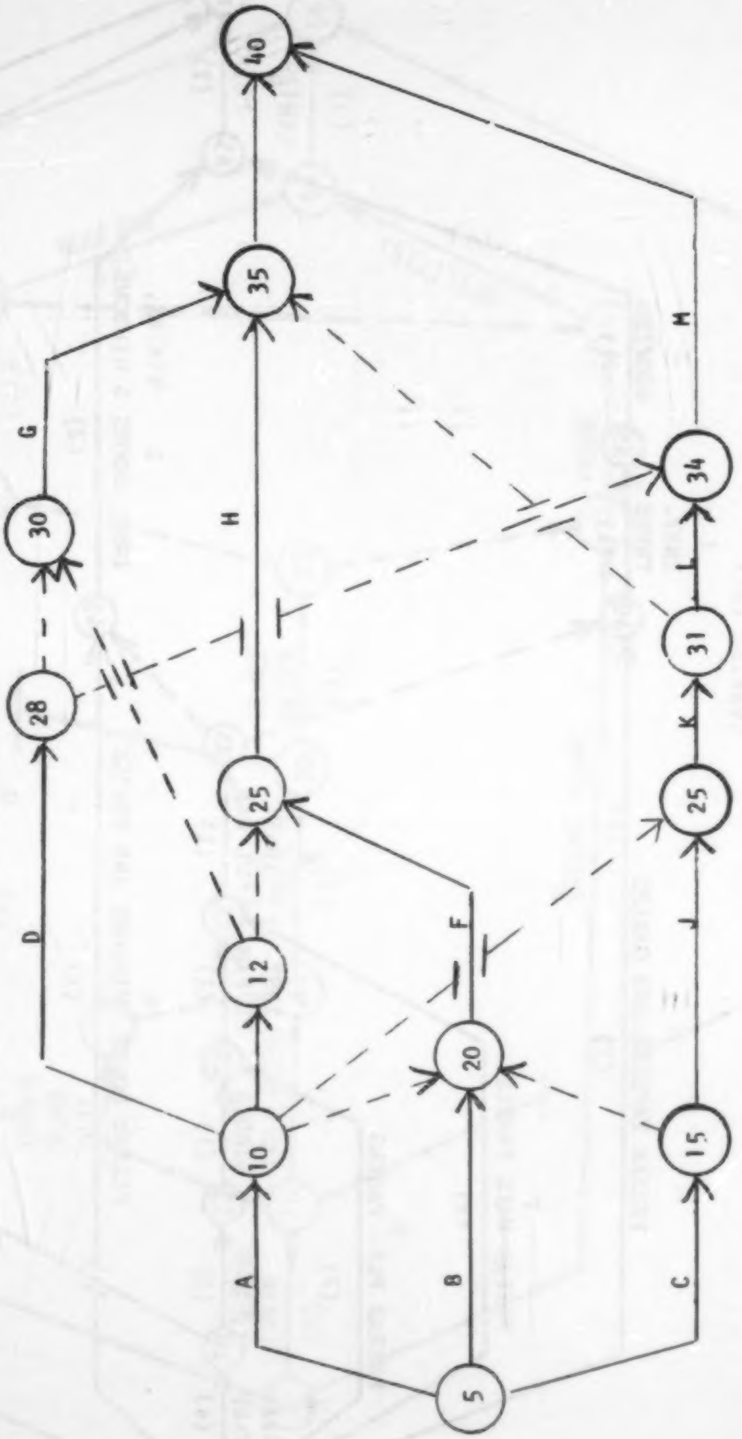
SOLUTION: PE VII, PART B, PAGE 54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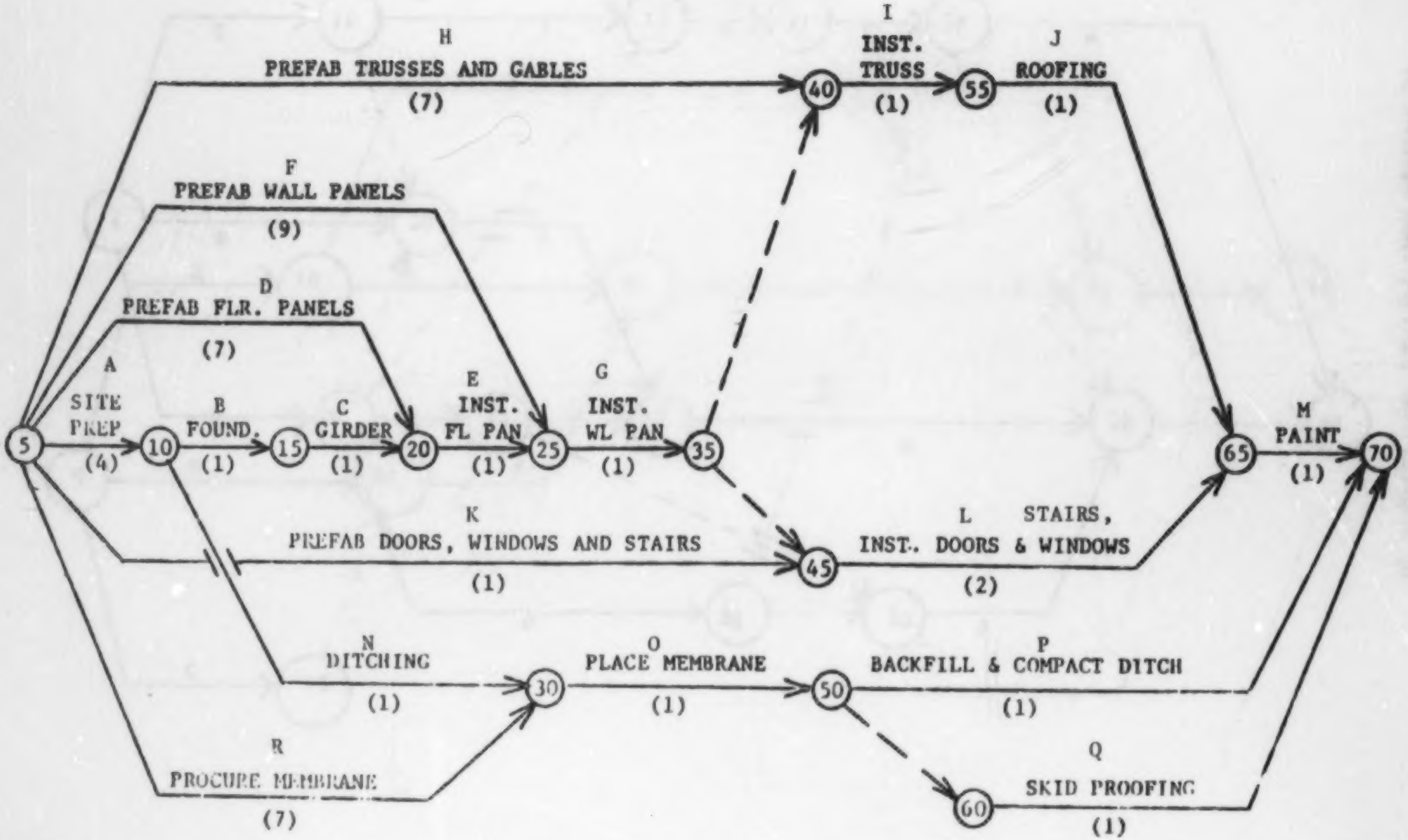
SOLUTION: PE VIII, PAGE 56

TRAINING BUILDING


H
PREFAB TRUSSES AND GABLES
(7)
I
INST.
TRUSS
(1)
J
ROOFING
(1)
F
PREFAB WALL PANELS
(9)
D
PREFAB FLR. PANELS
(7)
A
SITE
PREP
(4)
B
FOUND.
(1)
C
GIRDER
(1)
E
INST.
FL PAN
(1)
G
INST.
WL PAN
(1)
M
PAINT
(1)
K
PREFAB DOORS, WINDOWS AND STAIRS
(1)
L
INST. DOORS & WINDOWS
STAIRS,
(2)
N
DITCHING
(1)
O
PLACE MEMBRANE
(1)
P
BACKFILL & COMPACT DITCH
(1)
R
PROCURE MEMBRANE
(7)
Q
SKID PROOFING
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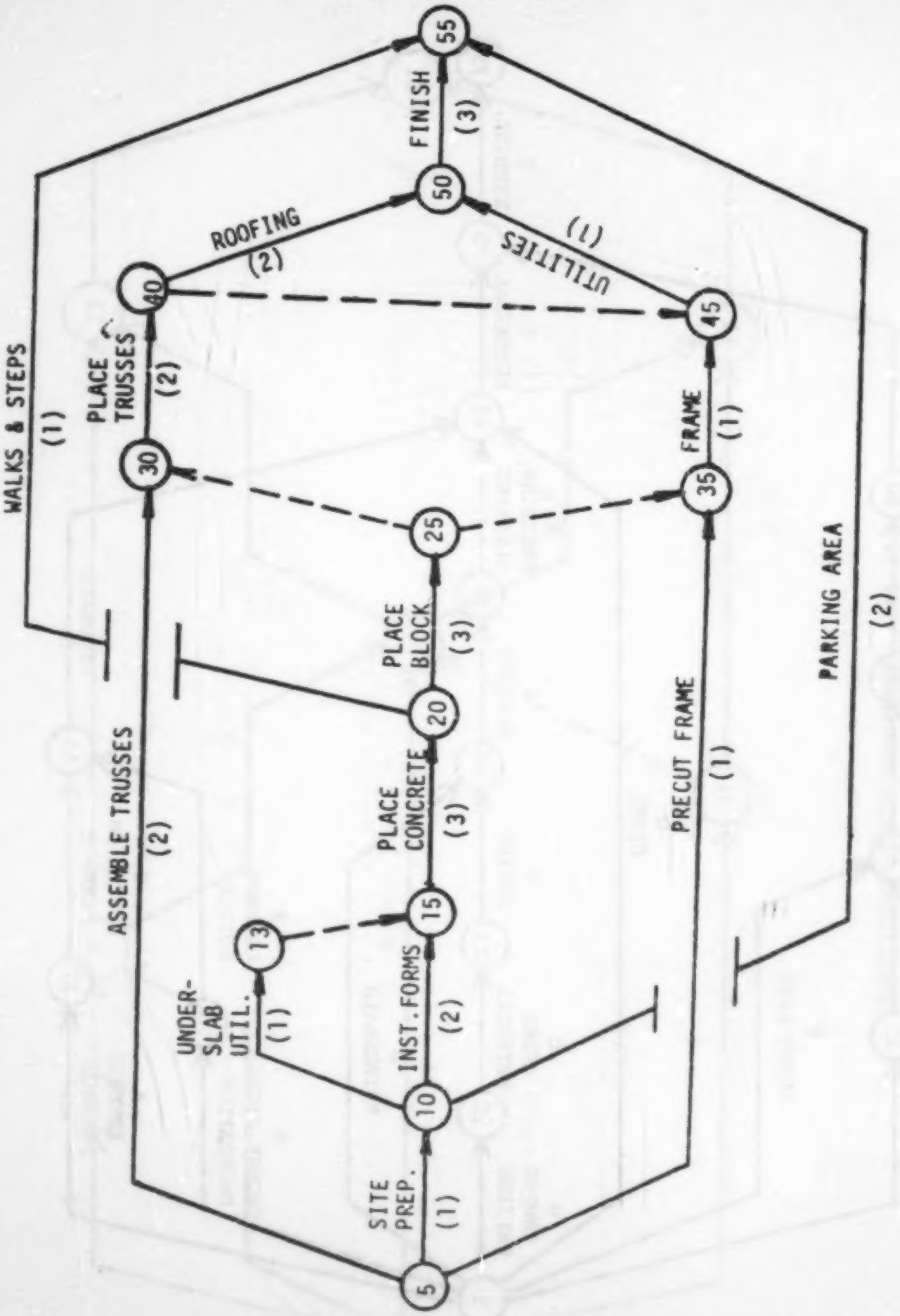
SOLUTION: PE IX, PAGE 58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SITE PREP.
(1)
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INST. FORMS
(2)
UNDER-SLAB UTIL.
(1)
13
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PLACE CONCRETE
(3)
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PLACE BLOCK
(3)
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ASSEMBLE TRUSSES
(2)
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PLACE TRUSSES
(2)
40
WALKS & STEPS
(1)
ROOFING
(2)
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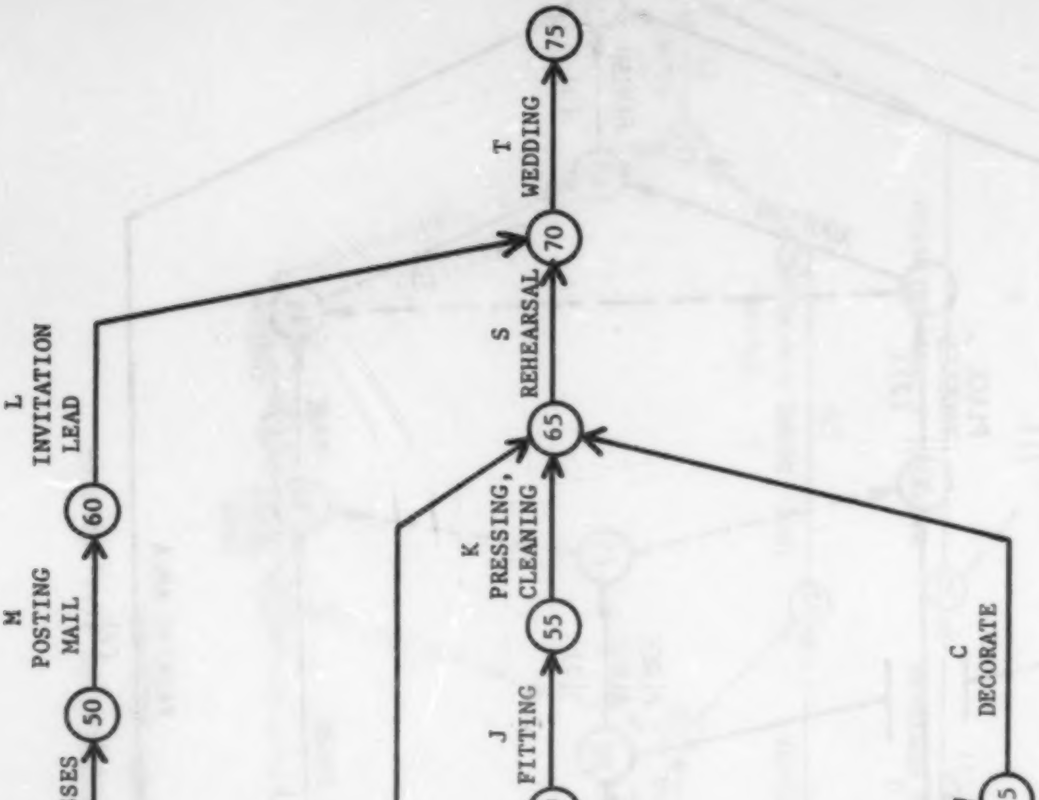
FINISH
(3)
55
PRECUT FRAME
(1)
35
FRAME
(1)
45
UTILITIES
(1)
PARKING AREA
(2)

SOLUTION: LOGIC PROBLEM I, PAGE 59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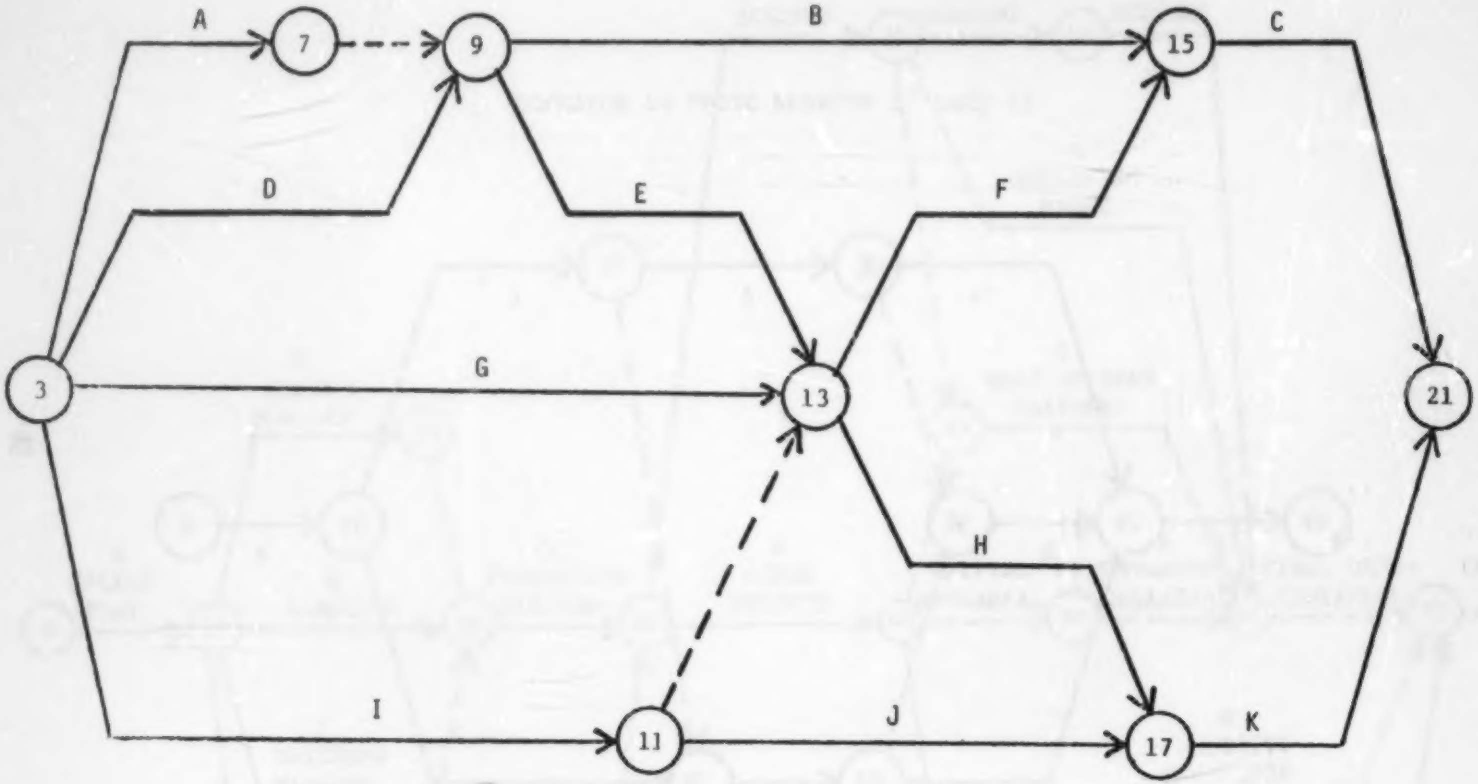
R CHOOSE INVITATIONS
Q PRINTER
N ADDRESSES
M POSTING MAIL
L INVITATION LEAD
P GUEST LIST
O GIFTS
G CHOOSE PATTERN
H ORDER MATERIAL
I SEWING
J FITTING
K PRESSING, CLEANING
S REHEARSAL
T WEDDING
D BRIDESMAID
E CHOOSE CAKES, DECORATION
F CATERER NOTICE
A RESERVE CHURCH
B NOTICE ON CHURCH
C DECORATE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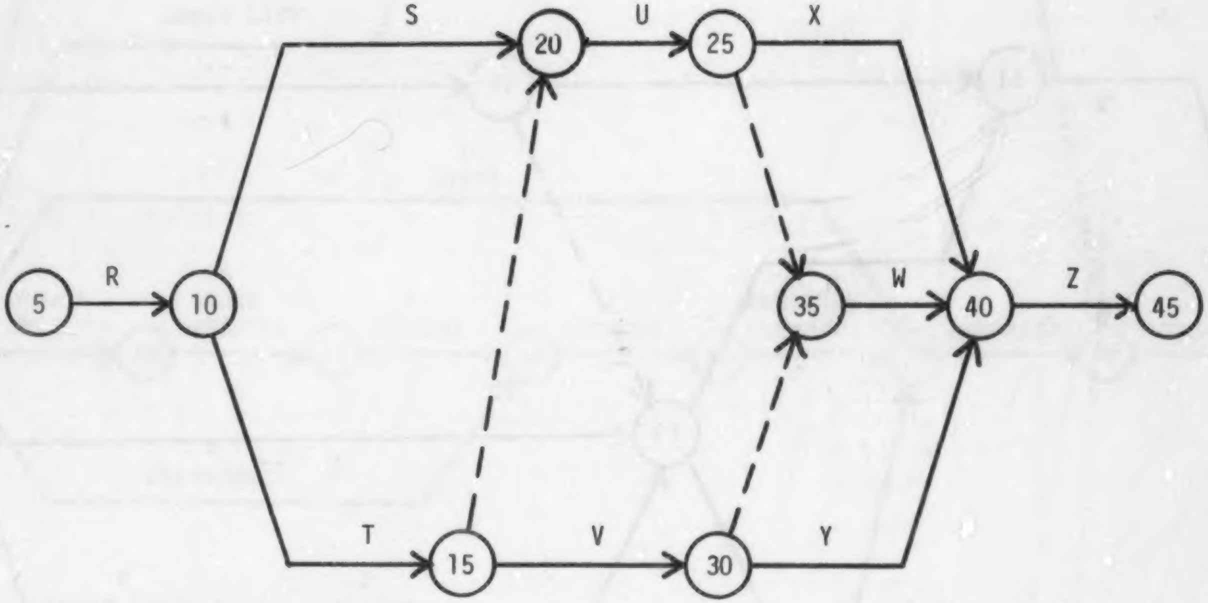
SOLUTION TO LOGIC PROBLEM 2, PAGE 61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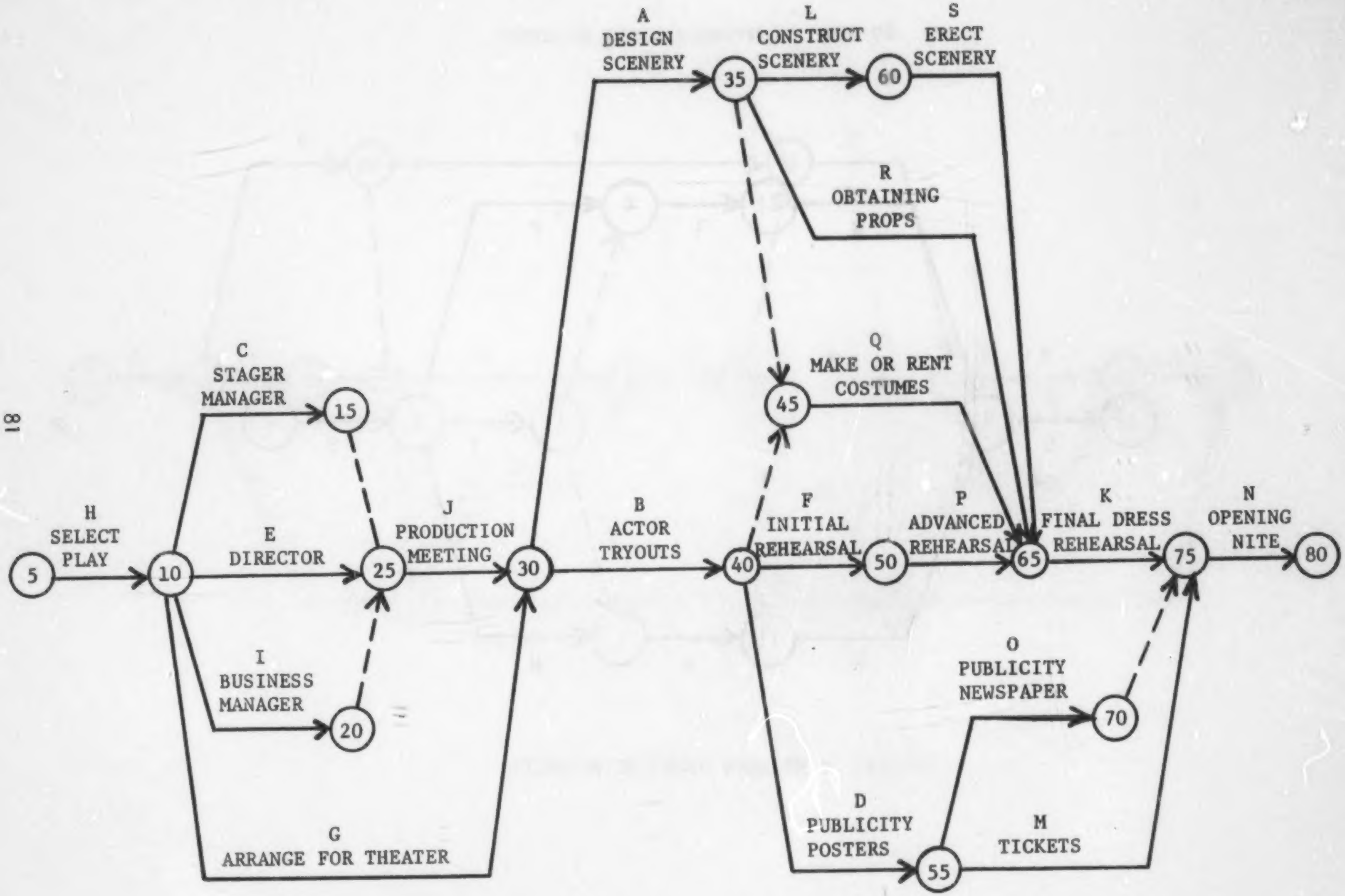
SOLUTION TO LOGIC PROBLEM 3, PAGE 62


H
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DESIGN
SCENERY
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ACTOR
TRYOUTS
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CONSTRUCT
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ERECT
SCENERY
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OBTAINING
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REHEARSAL
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ADVANCED
REHEARSAL
65
K
FINAL DRESS
REHEARSAL
75
N
OPENING
NITE
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PUBLICITY
POSTERS
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O
PUBLICITY
NEWSPAPER
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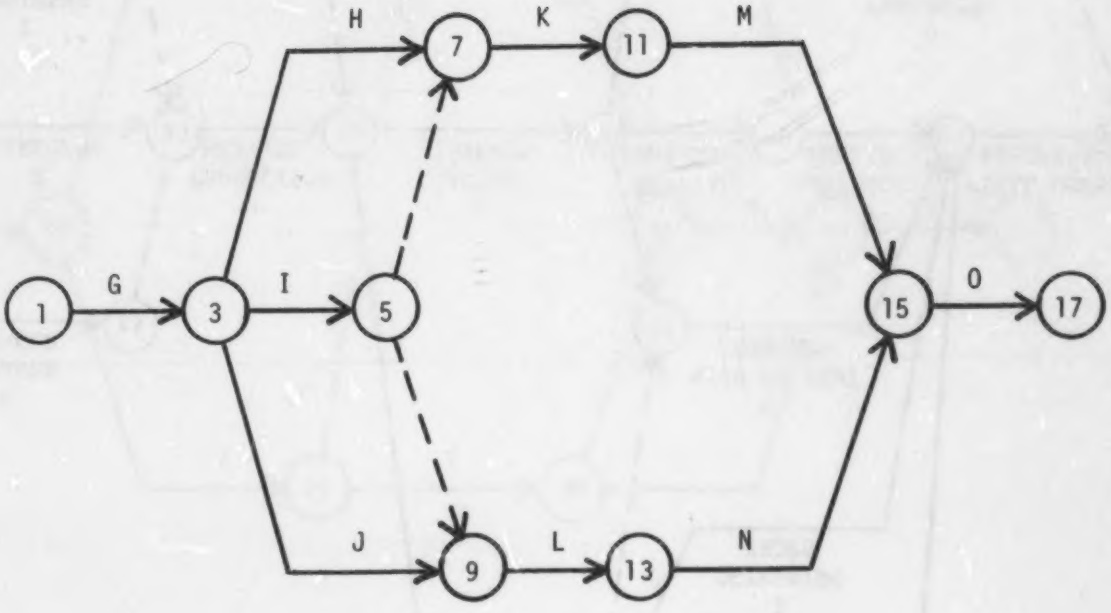
M
TICKETS

SOLUTION LOGIC PROBLEM 4, PAGE 63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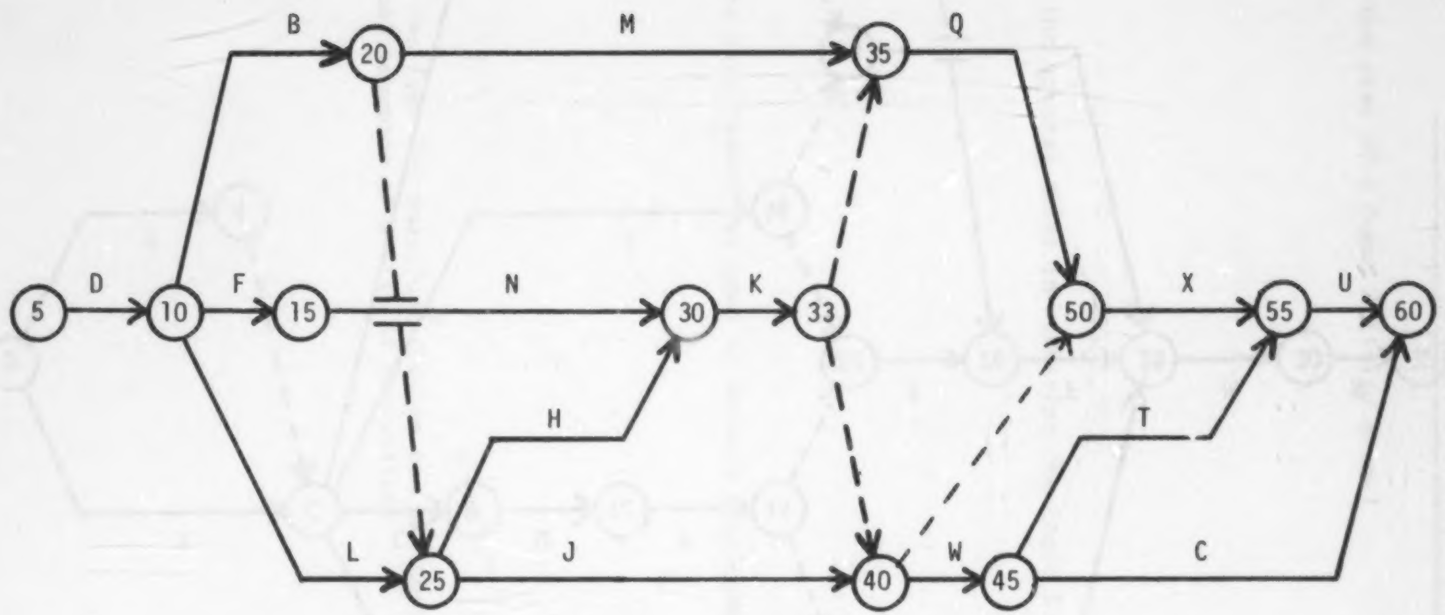
SOLUTION LOGIC PROBLEM 5, PAGE 65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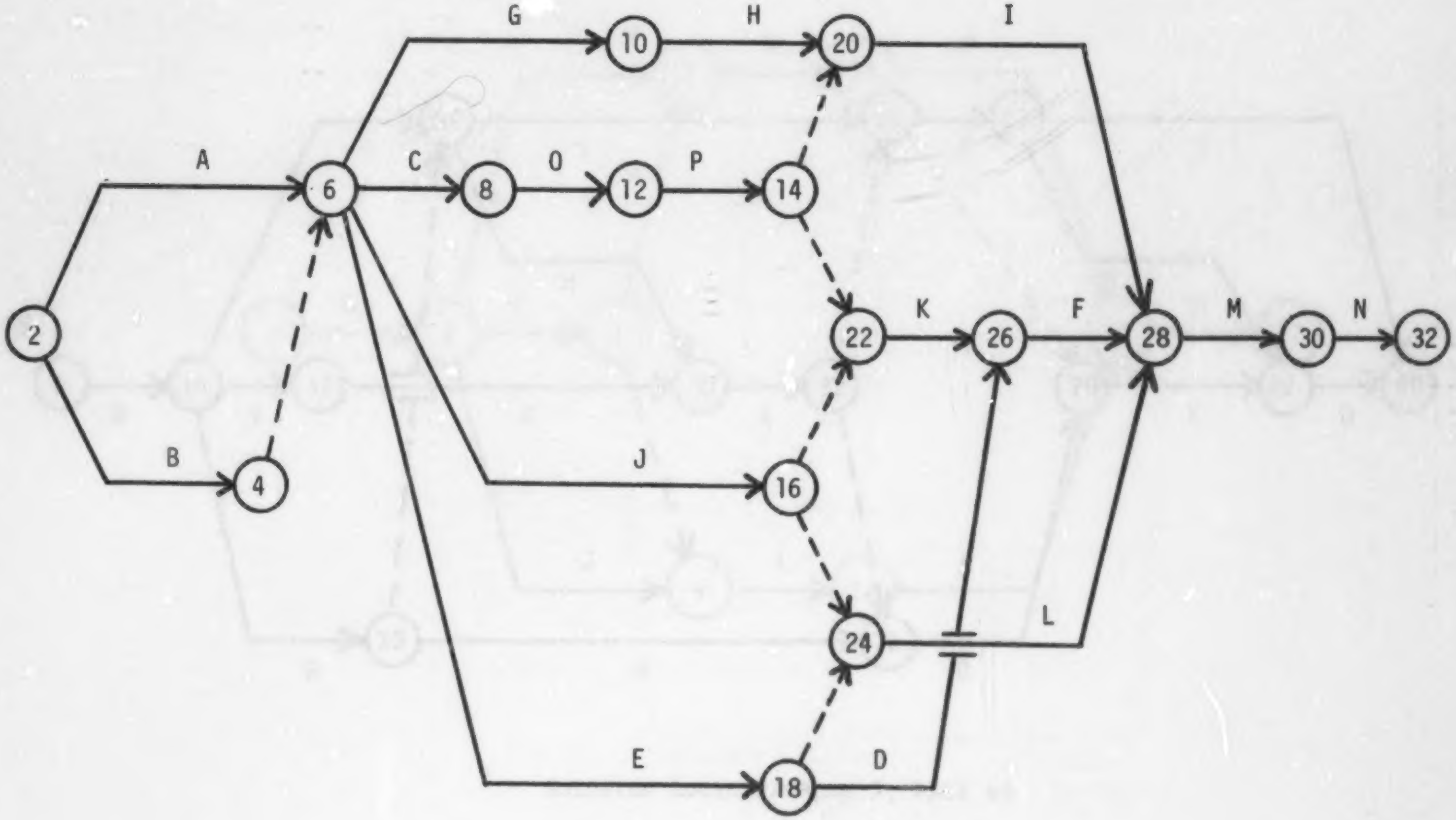
SOLUTION TO LOGIC PROBLEM 6, PAGE 66

SOLUTION LOGIC PROBLEM 7, PAGE 67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SELF-EVALUATION NETWORK DEVELOPMENT (1)

1) What are the uses of a Dummy Activity arrow?

2) What are the general rules in numbering the Logic Diagram?

3) Define the term "event" as used in Network Development.

4) What are the four (4) questions that we can ask ourselves when determining the logical sequence of a list of activities?

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ANSWERS TO SELF-EVALUATION QUIZ (1)

1) We use the Dummy Activity to:

   a) Maintain a logical sequence within the diagram.

   b) Prevent number duplication.

2) The general rules in numbering a diagram are:

   a) The number in the event node at the tail of an activity must be less than the number in the event node at the head of the activity.

   b) No two nodes can have the same number.

3) An event is an Instant in Time when an activity either begins or ends.

4) The four (4) questions that can be used to help determine the logical sequence of activities are:

   a) Can this activity start at the beginning of the project?

   b) What activities must be finished before this one begins?

   c) What activities may either start or finish at the same time this one does?

   d) What activities cannot begin until this one is finished?

SELF-EVALUATION NETWORK DEVELOPMENT

Develop an arrow logic network for the following curriculum with the given prerequisites. Number your completed diagram. There is only one beginning and one end to the course.

CURRICULUM	PREREQUISITES
Department of Economics	
ECO I Survey of Economics	None
ECO II Economic Development	ECO I
Department of Accounting	
ACCT I Accounting Systems	None
ACCT II Advanced Accounting	ACCT I
Department of Business Administration	
BA I Financial Decision Making	ACCT I, ECO I
BA II Seminar: Manufacturing Production	BA I, ECO II
BA III Managerial Statistics	ADPS I, MATH I
BA IV Management Planning and Control	BA III, ACCT II
Department of Automatic Data Processing Systems (ADPS)	
ADPS I Data Processing Systems	None
Department of Mathematics	
MATH I Introduction to Business and Economic Statistics	None
MATH II Quality Control and Reliability Techniques	MATH I
MATH III Mathematic Programming: Techniques and Applications	MATH I

Logic Diagram:

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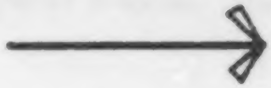
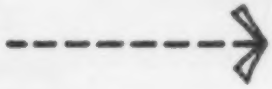
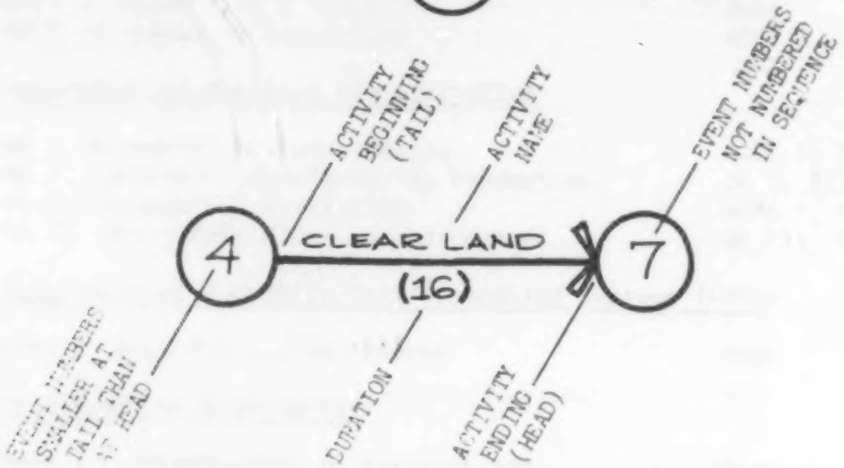
SYMBOLS

ACTIVITY ARROW		AN ACTIVITY IS A TIME CONSUMING OPERATION
DUMMY ARROW		PREVENTS NUMBER DUPLICATION AND SHOWS LOGICAL SEQUENCE (0 TIME)
EVENT NODE		INDICATES A POINT IN TIME


ACTIVITY BEGINNING (TAIL)
ACTIVITY NAME
EVENT NUMBERS NOT NUMBERED IN SEQUENCE
4
CLEAR LAND
7
(16)
EVENT NUMBERS SMALLER AT TAIL THAN AT HEAD
DURATION
ACTIVITY ENDING (HEAD)

ACTIVITY RELATIONSHIPS

1. CAN THIS ACTIVITY START AT THE BEGINNING OF THE PROJECT ?
2. WHAT ACTIVITIES MUST FINISH BEFORE THIS ONE BEGINS ?
3. WHAT ACTIVITIES MAY EITHER START OR FINISH WHEN THIS ONE DOES ?
4. WHAT ACTIVITIES CANNOT BEGIN UNTIL THIS ONE IS FINISHED ?

RESOURCE ESTIMATION

LESSON: RESOURCE ESTIMATION

OBJECTIVE: The student, using TM 5-333 and a prepared activity list, will be able to determine the duration for each activity after deciding on the quantity of materials, technology to be used, and the crew size.

REFERENCES: TM 5-333, chap. 5, and the tables in chaps. 6-17.
Programmed Text: Construction Estimating
Engineer Management Review Problems, Student Workbook

STUDENT NOTES

RESOURCE ESTIMATION

INTRODUCTION

Estimating is probably the most important input to the CPM process. lthough logic runs a close second, estimating is even more important. The stimator must be the most knowledgeable individual on the job. He has to nderstand how the job will be accomplished, and what alternative methods are vailable to accomplish each activity. The estimator also has to have a horough knowledge of the skill level of the individuals who will do the job n order to assign good sound work rates and efficiencies to the different rews. In short, the estimator and his estimates will either make or break he CPM process, because from this point on, everything will depend on the ctivity estimates.

The "ball park" estimates which are made during the preliminary planning tage yield approximate data for planning purposes, but they are not exact nough for the execution of construction tasks of any appreciable size or omplexity. More accurate, detailed estimates are vital to the successful lanning and execution of a mission.

Carelessly made estimates may lead to failure to meet completion dates; hey may cause uneconomical use of men, materials, and equipment; and they may eriously jeopardize a tactical or strategic situation. The military manager ust have competent estimators in his organization and should be a good stimator himself.

The estimating process consists of procedures designed to yield various esults. Initially, these results take the form of material requirements r bills of materials (BOM) and equipment/manpower requirements. Ultimately estimate of the time needed to accomplish each of the tasks in a project an be derived.

The procedure taught in the Engineer School is designed to permit even e inexperienced estimator to arrive at a reasonable task duration and be le to easily explain his rationale in deriving the duration.

General Estimating Procedure

(1) Study job directive
(2) Study plans and specifications
(3) Perform site investigation
(4) Prepare activities list
(5) Note work to be done by others
(6) Determine quantities for each activity
(7) Prepare Bill of Materials
(8) Determine resources available
(9) Determine technology for each activity
(10) Determine equipment/manpower for each activity
(11) Find the appropriate work rate
(12) Determine the troop effort
(13) Determine activity durations

Common Errors

(1) Picking figures out of the air
(2) Oversimplification
(3) Insufficient allowance for waste
(4) No allowance for delays
(5) Over-estimation of equipment capacity
(6) Failure to recompute for changes
(7) Not checking all computations and results

Qualifications of a Good Estimator

(1) Neat, methodical and organized
(2) Reads plans and specs accurately
(3) Knowledge and ability to assemble materials into workable units
(4) Intimate knowledge of what men and equipment will do
(5) Good knowledge of arithmetic

Activity Estimate Sheet:

We use an Activity Estimate Sheet as a format for estimating based on the procedures taught at USAES. While the format itself is not standard, it can be helpful as a guideline for estimating the material, manpower and equipment requirements for each activity. If you find that the format needs to be changed to fit your use, don't hesitate to do so. *

1. Material Take-Off: For this portion of the activity estimate, determine what types of materials are needed to complete the activity. This involves studying the plans and specifications in detail to insure that all necessary materials are included. Next calculate the quantity required for each material. For ordering materials, if appropriate, apply a waste factor to each of the materials. Combine the original quantity with the allowance for waste to determine the quantity of material to be ordered. Totaling all the material requirements for every activity in the project, a Bill of Materials can be made for the entire project.

The top part of an Activity Estimate Sheet looks like this:

PROJECT	ACTIVITY ESTIMATE SHEET				
Activity Description:					
	MATERIALS TAKE-OFF				
Material	Computations	Quan	Waste	Tot Quan	Remarks

* An example of an activity estimate sheet can be seen on page 96
The estimate sheet can be broken down into two main sections; (1) Materials Take-Off, and (2) Equipment-Manpower. Each section will be examined in detail.

pages tightly bound

ACTIVITY ESTIMATE SHEET

PROJECT:

ACTIVITY DESCRIPTION:

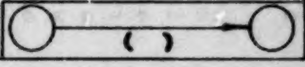
MATERIALS TAKE-OFF

MATERIAL	COMPUTATIONS	QUANTITY	WASTE	TOT. QUANT.	REMARKS

EQUIPMENT—MANPOWER

COMPONENT	TECHNOLOGY	QUANTITY	WORK RATE	STD. EFFORT	EFF.	TRP. EFFORT	CREW	DURATN.	REMARKS

SKILLS	EQUIPMENT OPERATORS	EQUIPMENT
Supervisors	Truck	Trucks
Carpenters	Dozer	Dozers
Plumbers	Scraper	Scrapers
Electricians	Grader	Graders
General Labor	Crane	Cranes
Masons	Mixer	Mixers
Painters	Roller	Rollers



EXAMPLE

Situation: You are working on a project to build a base camp. One of your activities is to place a 20' x 60' concrete slab six (6) inches thick.

A standard Waste Factor that is used in TM 5-302 is 10% for concrete.

This is how the Activity Estimate Sheet for our problem should look after following the procedures for estimating.

PROJECT Tent Pad ACTIVITY ESTIMATE SHEET

Activity Description: Place, spread and finish concrete; ready-mix; 4" slump.

MATERIALS TAKE-OFF

Material	Computations	Quan	Waste	Tot Quan	Remarks
Concrete	$\frac{20' \times 60' \times 1/2'}{27 \text{ cf}/_{\text{cy}}} = 22.2\text{cy}$	22.2 cy	10%	24.4 cy	

2. Equipment/Manpower: This portion is used to determine how long the activity will take. The component column is used if you have to break the activity into smaller parts to make estimating easier or if you must use more than one work rate in order to estimate the duration for the activity.

   a. Technology: In this space describe how you are going to do the job.

   b. Quantity: Put only the amount of material in the quantity column that will actually be worked. For example, an activity is to place a concrete slab which has a volume of 40 cubic yards. If you use a waste factor of 10% you will order 44 cubic yards on your Bill of Materials, but the actual amount of concrete that will be placed is only 40 cubic yards. However, if the activity were to transport the concrete to the job site then the quantity would be 44 cubic yards. Whether the quantity or the total quantity is used from the material take-off portion is dependent upon the type of activity, and your judgement.

   c. Work Rate: A work rate must be selected for the activity. The sources of work rates are: TM's. FM's, civilian texts, unit records, and your own experience. Choose a work rate that fits the activity and enter it in the Work Rate column exactly as shown. At this point check to see if the units in the quantity column and the workrate column are the same. If they are not, the quantity must be recalculated to agree with the units in the workrate.

   d. Standard Effort: The Standard Effort (STD EFF) is calculated using the formula:

      Standard Effort = Quantity x Work Rate

      Standard Effort is the ammount of effort expended in accomplishing a task by standard troops or equipment. This effort is usually expressed in terms of man-hours and equipment-hours. Standard or "book" troops can be thought of as having average experience and working under good conditions.

   e. Efficiency: The efficiency column is for you to establish an efficiency, shown as a percentage, for the crew that you pick for this activity. The efficiency considers how the task's difficulty, unit's training and job site conditions will effect the crew's performance. If you feel that the crew you pick can work as fast as the work rate says then the efficiency should be 100%. If you feel that because of inexperience or lack of proper tools that the crew cannot operate as fast as the work rate then give them a (fair) lower efficiency. This can also go the other way, if you feel that the men can operate faster than the given work rate then you may decide on higher than a 100% efficiency. You are or should be capable of evaluating your crews. Enter the efficiency in the efficiency column.

f. Troop Effort: After the efficiency is established the Troop Effort (TRP EFF) can be calculated. The standard effort states how much effort is necessary by the "book". The troop effort states how much effort the troops will have to expend to accomplish the book effort". To calculate troop effort use the formula:

$$\text{Troop Effort} = \frac{\text{Standard Effort}}{\text{Efficiency}}$$

Since the efficiency is shown as a percentage (100%) you must convert it into a decimal (1.00) then you can divide it into the Standard Effort. The answer you get is the Troop Effort (TRP EFF) and it will always be expressed as man-hours, man-days, man-weeks, or man-years, etc. It depends on how your Standard Effort is shown.

g. Crew Size and Duration: The next column is the crew column. The crew sizes given in TM 5-333 are only there to serve as a guide and are not meant to be the crew size. You must determine the most efficient crew size for each activity. Put the number of men or it might be equipment, in the crew column. Now we can determine the Duration which is the object of estimating manpower-equipment. To find the Duration we use the formula:

$$\text{Duration} = \frac{\text{Troop Effort}}{\text{Crew Size}}$$

The crew size only includes the personnel actually working. The supervisor is NEVER included in the crew size.

Duration equals the troop effort divided by the crew size. The duration will always be expressed as hours, days, weeks, months, or years. Enter the duration time in the Duration column of the activity estimate sheet. Now all your estimating for the activity is completed. This procedure should be followed for each and every activity in the project.

THREE RULES FOR ESTIMATING

1. STANDARD EFFORT = Quantity x Work Rate

2. TROOP EFFORT = $\frac{\text{Standard Effort}}{\text{Efficiency}}$

3. DURATION = $\frac{\text{Troop Effort}}{\text{Crew Size}}$

3. The above discussion on the equipment/manpower section of the activity estimate sheet was presented column by column for ease of explanation.

It is recommended that the following steps be used when actually performing an activity estimate.

a. Determine the technology.

b. Find a workrate that fits the activity description exactly. If this cannot be done break the activity into smaller components until several workrates can be found that will ultimately fit the activity description. Remember to get your NCO's involved since their experience is an outstanding source of information.

c. Determine the quantity of work to be performed. This may come from either the quantity or total quantity column of the material take-off section depending on the type of activity.

d. Determine the most efficient crew size for that activity.

e. Determine the efficiency expected to be experienced while performing the activity. The efficiency considers the task's difficulty, unit training, crew size and jobsite conditions.

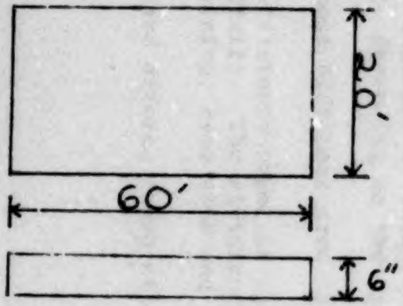
f. Calculate standard effort, troop effort and duration.

LEAD THROUGH PRACTICAL EXERCISE

PROJECT: Concrete Tent Pad ACTIVITY ESTIMATE SHEET

Activity Description: Place, Screed and Finish, Concrete, Ready-Mix, 4" Slump

MATERIALS TAKE - OFF

Material	Computations	Quan	Waste	Tot Quan	Remarks
					

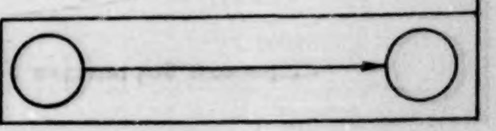
EQUIPMENT - MANPOWER

Component	Technology	Quan	Wrk Rate	Std Eff	Effic	Trn Eff	Crew	Dur	Remarks

SKILLS
Supervisors ____
Carpenters ____
Plumbers ____
Electricians ____
General Labor ____
Masons ____
Painters ____
________ ____

EQUIPMENT OPERATORS
Truck ____
Dozer ____
Scraper ____
Grader ____
Crane ____
Mixer ____
Roller ____
________ ____

EQUIPMENT
Trucks ____
Dozers ____
Scrapers ____
Graders ____
Cranes ____
Mixers ____
Rollers ____
________ ____



Estimating.

Using TM 5-333, the activity estimate sheet provided along with the estimating procedure taught, solve the following problems.

a) How long would it take 8 men working at 115% efficiency to build 1360 SF of 8" concrete block wall?

b) How long would it take 7 men working at 80% efficiency to install 210 feet of 15 inch vitrified clay pipe?

c) How much effort must your troops expend to install 3000 feet of 4 feet high chain link fence. The efficiency is 125%.

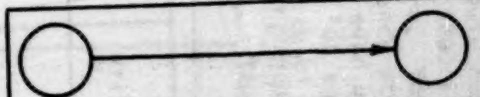
EQUIPMENT - MANPOWER

Component	Technology	Quan	Wrk Rate	Std Eff	Effic	Trp Eff	Crew	Dur	Remarks

SKILLS
Supervisors ____
Carpenters ____
Plumbers ____
Electricians ____
General Labor ____
Masons ____
Painters ____
____________ ____

EQUIPMENT OPERATORS
Truck ____
Dozer ____
Scraper ____
Grader ____
Crane ____
Mixer ____
Roller ____
____________ ____

EQUIPMENT
Trucks ____
Dozers ____
Scrapers ____
Graders ____
Cranes ____
Mixers ____
Rollers ____
____________ ____



RESOURCE ESTIMATING

STUDENT PRACTICAL EXERCISES

1. You have been directed to mix enough concrete for a building slab that measures 20' x 80' x 6" using a 16S mixer. DO NOT CONSIDER WASTE. You decide to use the 3d squad which has 8 men plus a squad leader. You estimate their efficiency factor to be 120%. What is the total number of hours required?

Quantity	Wk Rate	Std Effort	Effic	Trp Eff	Crew	Dur	Remarks

2. You have been assigned the mission to construct a concrete block wall that measures to be 300 feet long and 8 feet high; thickness is 8 inches. Since this is the first time your men have built a wall of this type you estimate their efficiency at 75%. Using 12 men, how long will it take to construct the wall?

Quantity	Wk Rate	Std Effort	Effic	Trp Eff	Crew	Dur	Remarks

3. You have been directed to do the electrical rough-in for a newly constructed barracks. A review of the plans indicate that there is 2800 linear feet of 1" conduit, fittings and outlet boxes within the structure. You plan to use 8 men to do the work and have estimated their efficiency at 120%. What is your estimated duration?

Quantity	Wrk Rate	Std Effort	Effic	Trp Eff	Crew	Dur	Remarks

4. You have been directed to place a concrete pad that measures 30' x 80' x 6" thick. Concrete buggies will be used to place the concrete into the forms. You estimate your efficiency at 110% and have a crew of 10 men plus a squad leader. What will be the duration of this activity?

Quantity	Wrk Rate	Std Effort	Effic	Trp Effort	Crew	Dur	Remarks

5. Now that you have placed and screeded the slab in problem 4 you now have to finish the surface. Using a crew of 6 men, you estimate their efficiency at 120%. How long will it take to finish the slab using trowels?

Quantity	Wrk Rate	Std Effort	Effic	Trp Effort	Crew	Dur	Remark

6. You have been assigned the project of roofing the supply building using asphalt shingles. You measure the roof and determine the size to be 36' by 62' with a pitch of 4 to 1 which figures to be 2,321 square feet. Using a typical crew, with an efficiency of 85%, how long will the project take?

Quantity	Wrk Rate	Std Effort	Effic	Trp Effort	Crew	Dur	Remarks

7. You have been assigned the mission of framing a new dining facility, including the interior walls. After reviewing the drawing you have determined that the structure requires 3,360 linear feet of 2" x 4" x 8' at 16" O.C. Using a crew of 4 men plus a supervisor working at 90% efficiency, what will be the duration of this activity?

Quantity	Wrk Rate	Std Effort	Effic	Trp Effort	Crew	Dur	Remarks

8. You now have the requirement to put siding on the dining facility which measures 30' x 100', the walls being 8' high, using T1-11 (plywood) siding material. Using a typical crew as shown in TM 5-333, working at 85% efficiency, what will be the duration of this project?

Quantity	Wrk Rate	Std Effort	Effic	Trp Effort	Crew	Dur	Remarks

pages tightly bound

9. The DEH has requested assistance to remove the snow from a range road. Your mission is to clear a 25-mile stretch of road that is 24 feet wide. You have 4 each 5-ton dump trucks. Each truck has a 6-foot wide plow. The depth of the snow is 4 inches. You estimate your efficiency at 75% How long will it take you to clear the road?

Quantity	Wrk Rate	Std Effort	Effic	Trp Effort	Crew	Dur	Remarks

10. You have been assigned the mission to install 850 feet of 6" Ø sewer line using vitrified clay pipe. You decide on a trench 2' wide and 5' deep. You have been assigned a ditching machine; however, backfill will be accomplished by hand and compaction will be accomplished using a pneumatic tamper. Using 3 crews of 6 men per crew, plus a leader working at an efficiency of 100%, what will be the duration of the project?

Quantity	Wrk Rate	Std Effort	Effic	Trp Effort	Crew	Dur	Remarks

11. You have been given the job of installing 600 feet of direct burial cable as part of a project to provide a lighting system for a multi-purpose athletic court. Trench excavation and backfill will be accomplished by hand. The workrate for backfilling is 360mh/1000 linear feet. Using a 6-man crew at an efficiency of 80%, what is the duration to excavate, install the cable and backfill?

EQUIPMENT - MANPOWER									
Component	Technology	Quan	Wrk Rate	Std Eff	Effic	Trp Eff	Crew	Dur	Remarks

12. As part of a messhall renovation project, you must estimate the time required to install three (3) each 36-inch exhaust fans with louvers approximately 7 feet above the floor. Using a 4-man crew at an efficiency of 75%, what is the duration to install the louvers and exhaust fans?

EQUIPMENT - MANPOWER									
Component	Technology	Quan	Wrk Rate	Std Eff	Effic	Trp Eff	Crew	Dur	Remarks

13. The floors in two of the workshops at the craft shop are to be surfaced with 9-inch square quarry tile. The rooms involved measure 20 ft x 30 ft and 50 ft x 60 ft. Using a 4-man crew plus supervisor at an efficiency of 90%, what is the duration for installing the quarry tile?

		EQUIPMENT - MANPOWER							
Component	Technology	Quan	Wrk Rate	Std Eff	Effic	Trp Eff	Crew	Dur	Remarks

14. You are required to install corrugated asbestos siding on four (4) identical buildings which are each 80 ft long, 20 ft wide, and 10 ft high. Using a crew of nine (9) men, including the supervisor, and working at an efficiency of 128%, what is the duration for installing the siding?

EQUIPMENT - MANPOWER									
Component	Technology	Quan	Wrk Rate	Std Eff	Effic	Trp Eff	Crew	Dur	Remarks

15. You have the mission to install 8 each wood double-hung windows and caulk them. The windows measure 4 ft x 5 ft each. The available personnel consist of 5 men and one supervisor who are 80% efficient. You decide to use TM 5-333 for your workrates and to start caulking the windows before finishing the installation. What is the minimum time it will take to install and caulk the windows?

		EQUIPMENT - MANPOWER							
Component	Technology	Quan	Wrk Rate	Std Eff	Effic	Trp Eff	Crew	Dur	Remarks

16. You must make and erect panel wall forms for a concrete wall measuring 6 ft high x 25 ft long x 5 ft thick. There are enough 100% efficient personnel for two crews of 3 men plus supervisors. You know the workrate for erecting panel wall forms to be 10mh/100 square feet from previous experience and will use TM 5-333 to find a rate for constructing the forms. If you can start erecting the forms after you are 20% complete making them, how long will it take to complete the entire activity?

EQUIPMENT - MANPOWER

Component	Technology	Quan	Wrk Rate	Std Eff	Effic	Trp Eff	Crew	Dur	Remarks

17. You have been assigned the task of insulating and installing plywood siding on 1000 SF of wall area. There are enough men for a typical crew as noted in TM 5-333 on each part of the activity and you feel that your people are 120% efficient. You are using thermal board for the insulation and can start on the siding after the insulation is 50% complete. How long will it take you to complete the activity? *** BE CAREFUL ***

		EQUIPMENT - MANPOWER							
Component	Technology	Quan	Wrk Rate	Std Eff	Effic	Trp Eff	Crew	Dur	Remarks

THE BRAIN BUSTER

18. Your unit has been assigned a mission to spread, shape and compact a 6-inch lift of base course material for a 180 ft x 360 ft vehicle handstand that will be surfaced with concrete. You plan to use a D7E dozer for spreading, two (2) CAT 12 graders for shaping and two (2) 8-ton tandem rollers for compacting. All equipment is operating at 100% efficiency. Utilizing TM 5-333, you determine the duration for spreading base course material to be four (4) hours. You decide to begin shaping the surface two (2) hours after the dozer starts spreading. If the entire activity duration is eleven (11) hours, how long after the graders start shaping must the rollers begin compacting?

EQUIPMENT - MANPOWER									
Component	Technology	Quan	Wrk Rate	Std Eff	Effic	Trp Eff	Crew	Dur	Remarks

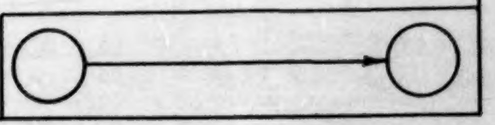
SOLUTION TO ESTIMATING PROBLEMS

		EQUIPMENT - MANPOWER							
Component	Technology	Quan	Wrk Rate	Std Eff	Effic	Trp Eff	Crew	Dur	Remarks
a		1360	110 MH/	149.6	115%	130.1	8 M	16.3	TM 5-333
		SF	1000 SF	MH		MH		HR	Table 10-1
b		210	.95 MH/	66.5	80%	83.1	7 M	11.9	TM 5-333
		FT	3 FT	MH		MH		HR	Table 13-4
c		3000	.75 MH/	225	125%	180	-	-	TM 5-333
		FT	10 LF	MH		MH			Table 15-3

SKILLS
Supervisors ____
Carpenters ____
Plumbers ____
Electricians ____
General Labor ____
Masons ____
Painters ____
____________ ____

EQUIPMENT OPERATORS
Truck ____
Dozer ____
Scraper ____
Grader ____
Crane ____
Mixer ____
Roller ____
____________ ____

EQUIPMENT
Trucks ____
Dozers ____
Scrapers ____
Graders ____
Cranes ____
Mixers ____
Rollers ____
____________ ____



WORK SPACE

SOLUTIONS

EQUIPMENT - MANPOWER

	Component	Technology	Quan	Wrk Rate	Std Eff	Effic	Trp Eff	Crew	Dur	Remarks
1.	Mix concrete	16 Mixer	29.63cy	2.0MH/ cy	59.26MH	1.20	49.38MH	8M	6.17 hr	TM 5-333, Table 8-1
2.	Block wall		2400SF	110MH/ 1000SF	264MH	.75	352MH	12M	29.33 hr	Table 10-1
3.	Electrical Rough-in		2800LF	320MH/ 1000LF	896MH	1.20	746.67 MH	8M	93.33 hr	Table 12-5
4.	Place concrete	Concrete Buggies	44.44cy	1.25MH/ cy	55.55MH	1.10	50.5MH	10M	5.05 hr	Table 8-1
5.	Finish concrete	Trowels	2400SF	2.5MH/ 100SF	60MH	1.20	50MH	6M	8.33 hr	Table 8-3
6.	Roofing	Asphalt Shingles	2321SF	30MH/ 1000SF	69.63 MH	.85	81.92MH	4M	20.5 hr	Table 11-3
7.	Framing	Note: .667 $^{bf}/_{lf}$	2241.12 bf	56MH/ 1000bf	125.5 MH	.90	139.44 MH	4M	34.86 hrs	Table 9-1
8.	Siding		2080SF	24MH/ 1000SF	49.92 MH	.85	58.73 MH	8M	7.34 hr	Table 9-2
9a.	Snow Removal		25 mi	.15EH/ mi	3.75 EH	.75	5EH	1	5 hr	Table 17-2
		OR								
9b.	Snow Removal	″	100 mi	.15EH/ mi	15 EH	.75	20.EH	4	5 hr	Table 17-2
10.	DIG	ditching machine	313.81 cy	2.9 hr/ 1000cy	.92 hr	1.00	.91 hr	1	.91hr	Table 6-3
	INSTALL		340jt.	.25MH/ jt.	85MH	1.00	85MH	6M	14.16 hr	Table 13-4
	BACKFILL	by hand	314.81 cy	.75MH/ cy	236.11 MH	1.00	236.11 MH	6M	39.35 hr	Table 6-3
	COMPACT	pneumatic tamper	314.81 cy	.7MH/ cy	220.37 MH	1.00	220.37 MH	6M	36.73 hr	Table 6-3

SOLUTIONS

	Component	Technology	Quantity	Workrate	Standard Effort	Effi-ciency	Troop Effort	Crew	Duration	Remarks
11.	Excavate	by hand	600 lf	640mh/ 1000 lf	384mh	80%	480mh	6men	80 hr	TM 5-333, table 12-2
	Install Cable	by hand	600 lf	48mh/ 1000 lf	28.8mh	80%	36.0mh	6men	6.0 hr	TM 5-333, table 12-2
	Backfill	by hand	600 lf	360mh/ 1000 lf	216mh	80%	270mh	6men	45 hr	Previous experience
				Since only one crew is available the time of 131 hr is required						
12.	Fans	by hand	3 each	6mh/ unit	18mh	75%	24mh	4men	6 hr	TM 5-333, table 14-3
	Louvers	by hand	3 each	16mh/ unit	48mh	75%	64mh	4men	16 hr	TM 5-333, table 14-3
									22 hr	

	Component	Technology	Quantity	Workrate	Standard Effort	Efficiency	Troop Effort	Crew	Duration	Remarks
13.	Quarry Tile		3600 sf	80mh/ 1000 sf	288mh	90%	320mh	4men	80 hr	TM 5-333, table 10-3
14.	Siding		8000 sf	32mh/ 1000 sf	256mh	128%	200mh	8men	25 hr	TM 5-333, table 9-2
15.	Windows		8 ea	2.5mh/ each	20mh	80%	25mh	4men	6.25 hr	TM 5-333, table 9-7
	Caulking		144 lf	16mh/ 1000 lf	2.3mh	80%	2.9mh	1man	2.9 hr	TM 5-333, table 9-7

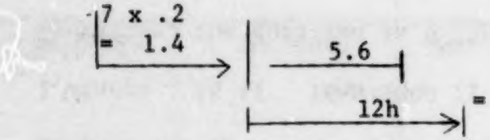
Since work can begin on the caulking while the windows are being installed the minimum duration would be the time to install the windows plus the time to caulk the last window.

1 window 18 lf 16mh/1000 lf .29mh 80% .36mh

Therefore, the duration is 6.25hr + .36hr = 6.61 hours to install the windows and caulk them.

16.

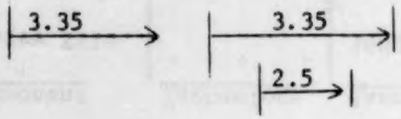
Component	Technology	Quantity	Workrate	Standard Effort	Effi-ciency	Troop Effort	Crew	Duration	Remarks
Make forms		360 sf	5.8mh/ 100 sf	20.9mh	100%	20.9mh	3men	7 hr	TM 5-333, table 8-5
Erect forms		360 sf	10mh/ 100 sf	36mh	100%	36mh	3men	12 hr	Previous experience



= 13.4 hours minimum duration.

17.

Component	Technology	Quantity	Workrate	Standard Effort	Effi-ciency	Troop Effort	Crew	Duration	Remarks
Insulate	Thermal board	1000 sf	32mh/ 1000 sf	32mh	120%	26.7mh	[illegible]men	6.7hr	TM 5-333, table 9-4
Siding	Plywood	1000 sf	24 mh/ 1000 sf	24mh	120%	20mh	8men	2.5hr	TM 5-333, table 9-2

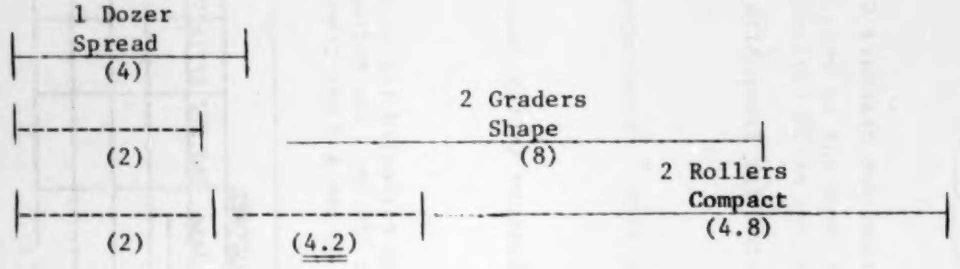


impossible

The minimum duration is the time for the insulation, 6.7 hrs, plus the time to put on the last bit of siding. I would use an estimate of 7 hours.

SOLUTIONS

	Component	Technology	Quantity	Workrate	Standard Effort	Effi-ciency	Troop Effort	Crew	Duration	Remarks
18.	Spreading	Machine	1200 CY	3.33/1000	4	100%	4	1	4	TM 5-333, table 6-5
	Shaping	Machine	7200 SY	2.22/1000	15.98	100%	15.98	2	8	TM 5-333, table 6-5
	Compacting	Machine	7200 SY	1.33/1000	9.58	1000%	9.58	2	4.8	TM 5-333, table 6-5


1 Dozer
Spread
(4)
(2)
2 Graders
Shape
(8)
(2)
(4.2)
2 Rollers
Compact
(4.8)

ANSWER: Rollers must begin compacting not later than 4.2 hours after graders start shaping to finish the entire activity in eleven (11) hours.

SELF-EVALUATION RESOURCE ESTIMATING (1)

1) Is the bill of materials (BOM) computed from the Quantity column or Total Quantity column?

2) Name two qualifications of a good estimator.

3) Name two common errors in estimating.

4) What goes under the technology column?

5) What is the equation for Standard Effort?

6) What is the equation for Troop Effort?

7) TROOP EFFORT/CREW SIZE = ______________________________.

8) Where is the Efficiency factor found?

9) A young NCO has estimated the standard (book) effort for an activity to be 150 mh. You estimate the efficiency to be 120% and plan to use a 5 man crew. The duration will be?

EQUIPMENT - MANPOWER								
	Quan	Wrk Rate	Std Eff	Effic	Trp Eff	Crew	Dur	Remarks
	—	—						—

SELF-EVALUATION RESOURCE ESTIMATING (2)

1) If your crew is not as skilled as an average crew, you can change the workrate to compensate? TRUE - FALSE

2) If the efficiency is greater than 100% explain why the Troop Effort will be larger or smaller than the Standard Effort?

3) You had to estimate an activity duration by evaluating two parts of the activity. The activity duration is the sum of those two parts. TRUE - FALSE Explain:

4) The supervisor is not part of the crew size in the estimating procedure. Explain why this key individual is omitted?

5) How is the Remarks column used?

SOLUTIONS TO SELF-EVALUATION (1)

1. **Total Quantity.**

2. **Any two of the following:**

   Qualifications of a Good Estimator:

   (1) Neat, methodical and organized
   (2) Reads plans and specs accurately
   (3) Knowledge and ability to assemble materials into workable units
   (4) Intimate knowledge of what men and equipment will do
   (5) Good knowledge of arithmetic

3. **Any two of the following:**

   Common Errors:

   (1) Picking figures out of the air
   (2) Oversimplification
   (3) Insufficient allowance for waste
   (4) No allowance for delays
   (5) Over-estimation of equipment capacity
   (6) Failure to recompute for changes
   (7) Not checking all computations and results

4. The method that is going to be used to accomplish the job.

5. STANDARD EFFORT = Quantity x $^{\text{Manhours}}/_{\text{unit}}$

   or Quantity x Workrate

6. Troop Effort = $^{\text{Standard Effort}}/_{\text{Efficiency}}$

7. Duration

8. It is not found anywhere. It is determined by the Estimator on the basis of such things as experience, weather, site, equipment, workload, etc.........

9. 25 Hrs.

SCHEDULE DEVELOPMENT

LESSON: NETWORK TIME ANALYSIS

OBJECTIVE: The student, given a completed network and the estimated durations for each activity, will be able to determine the early and late event times for each activity, and the critical activities in the network.

REFERENCES: TM 5-333, para 2-6 thru 2-9.
Programmed Text: Network Time Development
Engineer Management Review Problems Student Workbook

STUDENT NOTES

1. INTRODUCTION

The determination of the logic diagram and the estimation of the duration of each activity completes the hardest part of the project management process. The remaining steps are quick and easy in comparison with the tremendous amount of management information that is gained. Every manager is constantly asked many questions about his project. The manager performs a process called Time Analysis, to be able to provide answers regarding the project duration; early start and late finish times for any activity; and critical activities within the project.

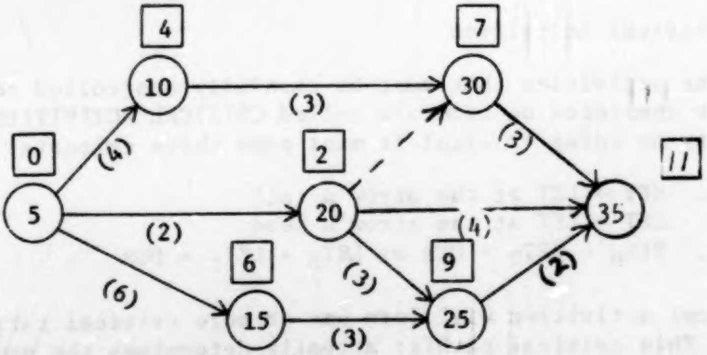
2. TIME ANALYSIS

a) The Time Analysis is based on the results of two other steps of the project management process, using the logic diagram determined in Project Planning and the activity durations from the resource estimation procedure. The first step is to add the activity durations to the network. This is done by placing the duration in brackets under the activity arrow. A key point to remember is that all durations must be in the same time unit (hours, days, weeks, etc).

b) Early Event Times

An event occurs when all activities ending at an event node have been completed; this is the earliest possible time that the event can occur and is called the Early Event Time (EET). This number will be placed in a box above each event node.

The calculations are begun by entering a zero in the box above the first event node. This means that at the End of time unit zero (0) the project will begin. Working through the network from left to right, following the arrows, add the activity duration, to the EET at the tail of the arrow and enter the sum in the box of the event node at the head of the arrow. In cases where more than one activity ends at an event node always use the largest number, since the event cannot take place until all activities ending at the node have been completed.

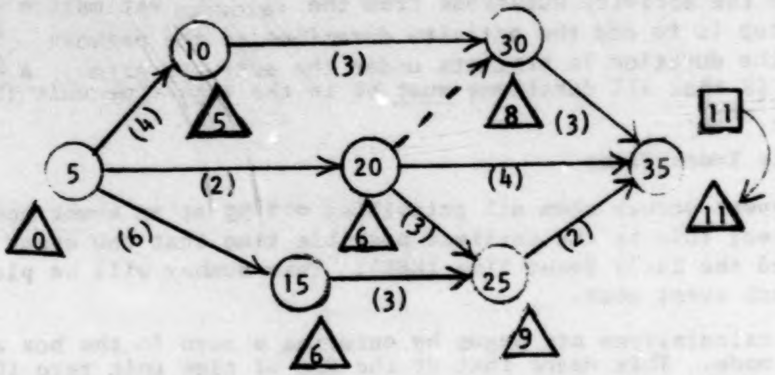


The number above the last event node will be the project's earliest possible completion time. At the end of that time period the project should be complete.

c) Late Event Times

The next step is to determine the latest possible time each event can occur and NOT DELAY THE PROJECT'S COMPLETION TIME. This is the Late Event Time (LET) and will be placed in a triangle beneath each event node.

To calculate LET's enter the Early Event Time in the square at the last event node of the project as the beginning LET in the triangle beneath the last event node. This will ensure that the project's completion time will be met. Then working from right to left, going against the arrows, subtract the activity duration from the LET at the head of the arrow and enter it in the triangle at the tail of the arrow. In situations involving multiple activities leaving an event node always use the smaller number.



Note that the calculation of the LET is the reverse of the calculation of the EET. Remember in calculating the EET and LET to include dummy activities and as a check, at least one path will produce an LET=0 at the first event node.

d) Critical Activities

The activities that must be carefully controlled to ensure that the project is completed on time are called CRITICAL ACTIVITIES. To identify an activity as being critical it must pass three criteria:

a. EET = LET at the arrow's tail
b. EET = LET at the arrow's head
c. $EET_H - EET_T = DUR$ or $LET_H - LET_T = DUR$

The critical activities will form one or more critical paths through the network. This critical path(s) actually determines the project's completion time. It is the longest time path through a network and if any activity on the critical path is delayed the project will be delayed.

Some other characteristics of the critical path are:

a. it must be continuous
b. it can contain dummy activities
c. there can be more than one
d. it has no float

The critical path is indicated on the logic diagram by double lining critical activities and dummy arrows which lie on the critical path. A completed logic diagram will supply the user with a great deal of information. Some information that can be obtained from a logic diagram is:

Early Start (ES): This is the earliest time an activity can start. The ES for an activity equals EET at the tail of an activity plus one (1).

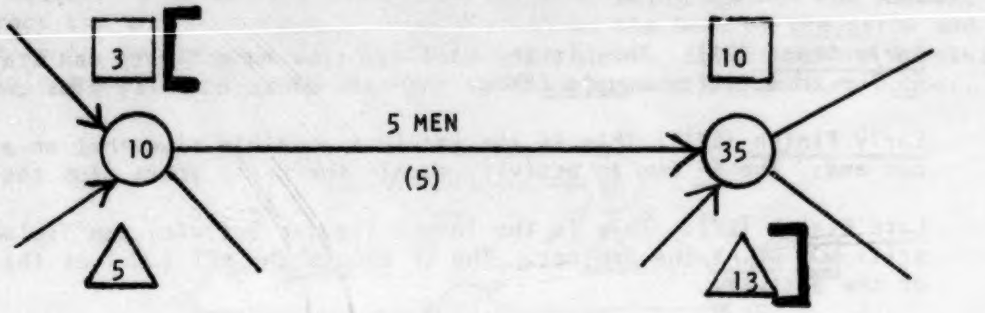
Early Finish (EF): This is the earliest possible time that an activity can end. The EF for an activity equals the Early Start plus the duration.

Late Finish (LF): This is the latest time an activity can finish and still NOT DELAY the project. The LF equals the LET (△) at the head of the activity.

Late Start (LS): This is the latest time an activity can start and NOT DELAY the project. The LS equals the LET (△) at the head of an activity minus the duration of that activity.

Interfering Float (IF): This is the time when an activity, if delayed, will directly effect one or more activities. The IF for an activity equals the difference between the LET and EET at the head of the activity.

ACT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
10-35				[5	5	5	5	5			X	X	X]		



ES = 4th Time Unit

EF = 8th Time Unit

LS = 9th Time Unit

LF = 13th Time Unit

IF = 3 Time Units

CREW = 5 Men

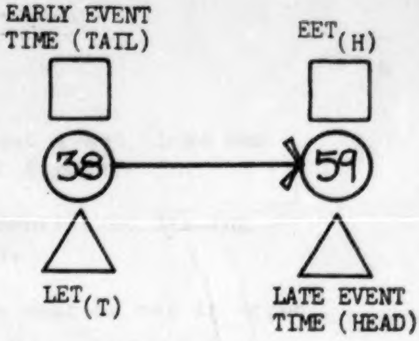
DUR = 5 Time Units

FF = 2 Time Units

REFERENCE

EET
- WORK FROM LEFT TO RIGHT
- IF HAVE CHOICE USE LARGEST
- $EET_{(H)} = EET_{(T)} + DUR$

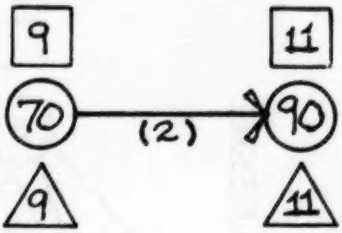
LET
- WORK FROM RIGHT TO LEFT
- IF HAVE CHOICE USE SMALLEST
- $LET_{(T)} = LET_{(H)} - DUR$


EARLY EVENT TIME (TAIL)
EET(H)
38
59
LET(T)
LATE EVENT TIME (HEAD)

CRITICAL ACTIVITY CRITERIA

ALL 3 CRITERIA MUST BE SATISFIED FOR ACTIVITY TO BE CRITICAL

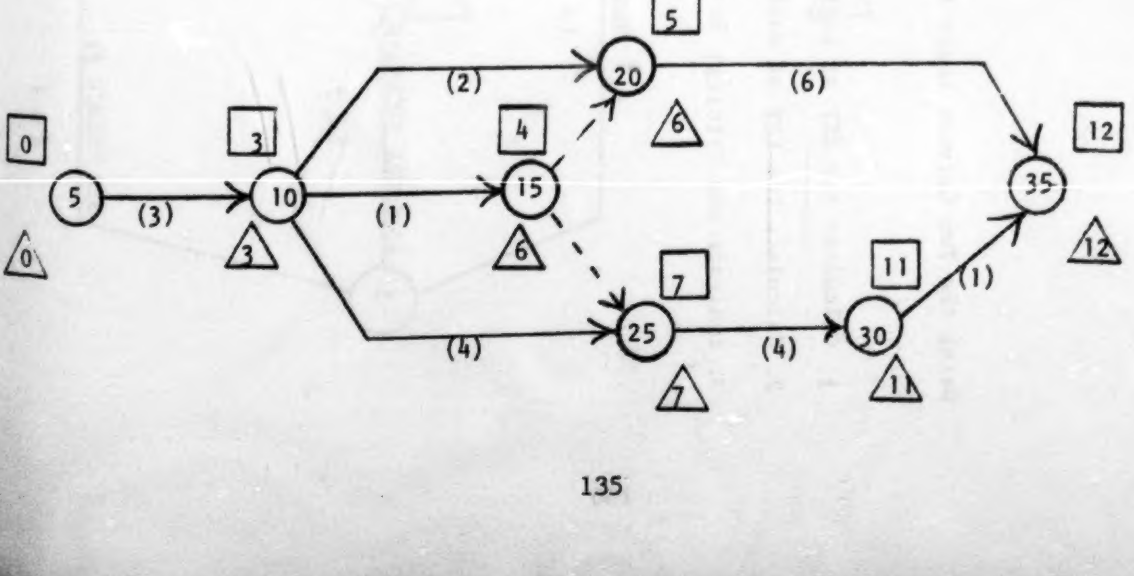
1. $EET_{(T)} = LET_{(T)}$
2. $EET_{(H)} = LET_{(H)}$
3. $EET_{(H)} - EET_{(T)} = DUR$
   OR
   $LET_{(H)} - LET_{(T)} = DUR$


9
11
70
(2)
90
9
11

** EXCEPTION: If there are ONLY dummy arrows leaving the activity, then

$$I.F. = LET_H - \text{Smallest } EET_{\text{Head of Dummy(s)}}$$

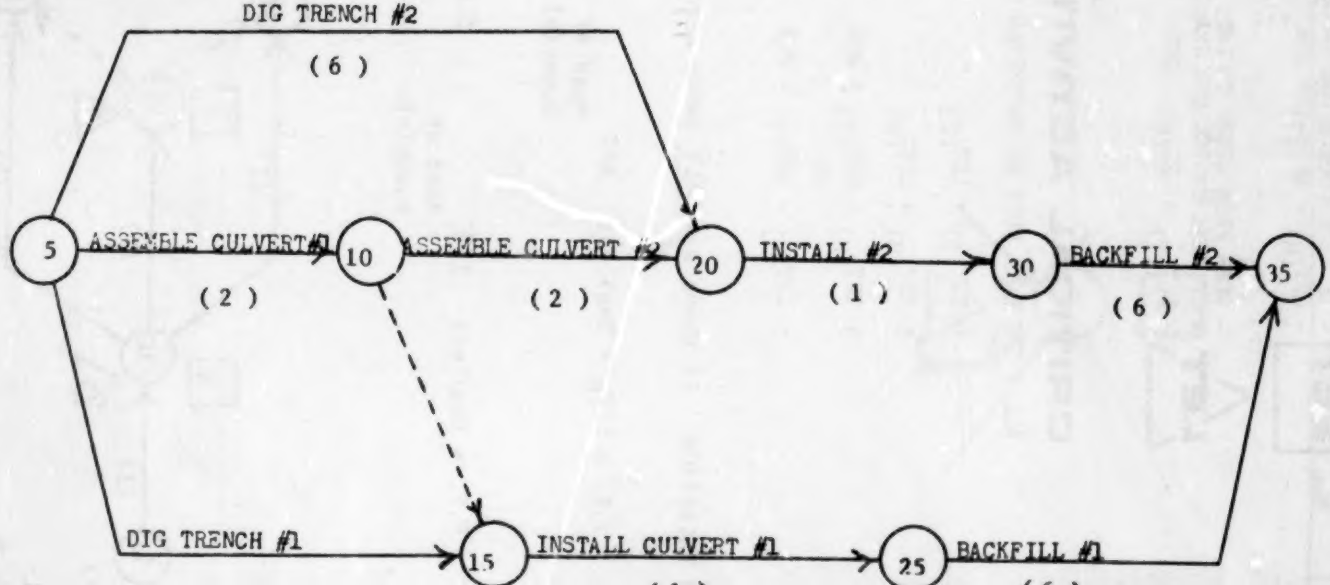
$$F.F. = \text{Smallest } EET_{\text{Head of Dummy(s)}} - E.F.$$


0
5
0
(3)
3
10
3
(2)
(1)
(4)
4
15
6
5
20
6
(6)
7
25
7
(4)
11
30
11
(1)
12
35
12

TIME ANALYSIS PRACTICAL EXERCISE

Using the Two Culvert Logic Diagram below:

1. Calculate the EET at each event node.
2. Calculate the LET at each event node.
3. Indicate the Critical Activities.

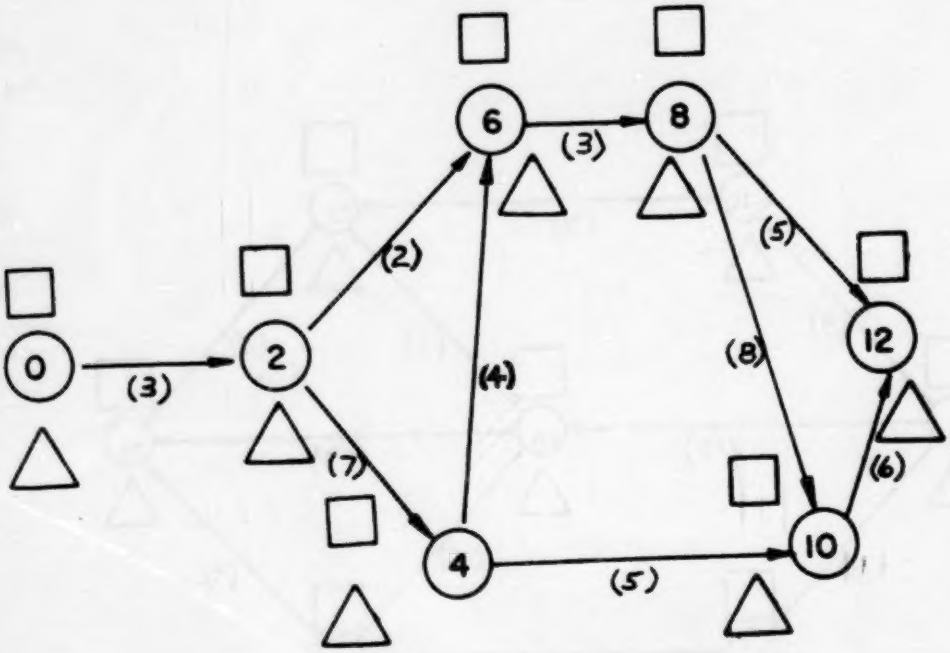

DIG TRENCH #2
(6)
5
ASSEMBLE CULVERT #1
(2)
10
ASSEMBLE CULVERT #2
(2)
20
INSTALL #2
(1)
30
BACKFILL #2
(6)
35
DIG TRENCH #1
15
INSTALL CULVERT #1
25
BACKFILL #1

STUDENT PRACTICAL EXERCISE I

Requirement: a. Calculate the earliest and latest event times and insert in appropriate geometric figure.

b. Select the Critical Path and identify by drawing lines parallel to selected path.

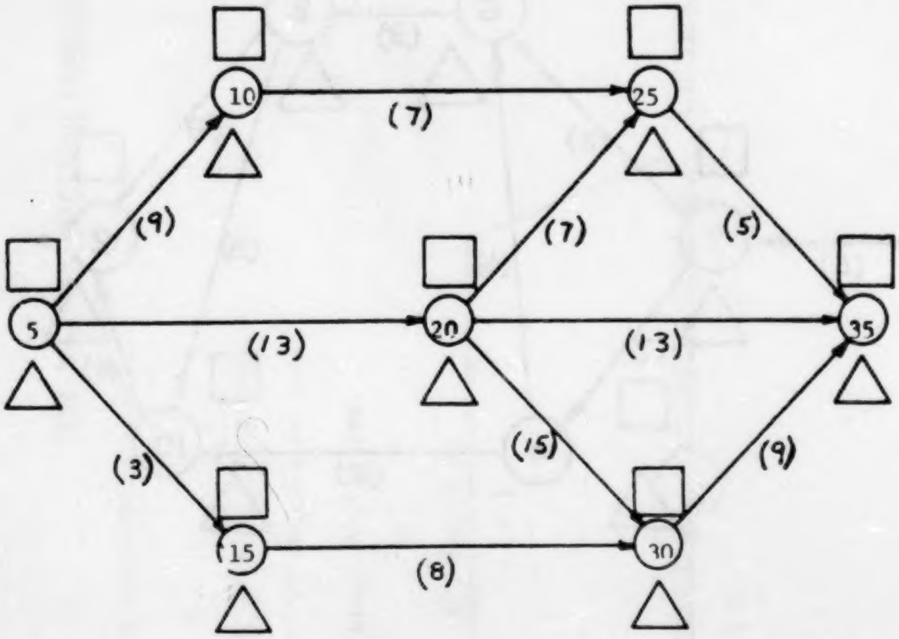
c. List the three conditions which must be met in order for an activity to be critical.



STUDENT PRACTICAL EXERCISE II

Requirement A: Calculate the Earliest Event Time for each event and place answer in square provided over appropriate number.

Requirement B: Calculate the latest event times and insert answers in triangles under appropriate numbers.



10
25
5
20
35
15
30
(9)
(7)
(13)
(7)
(5)
(13)
(3)
(15)
(9)
(8)

Time Analysis

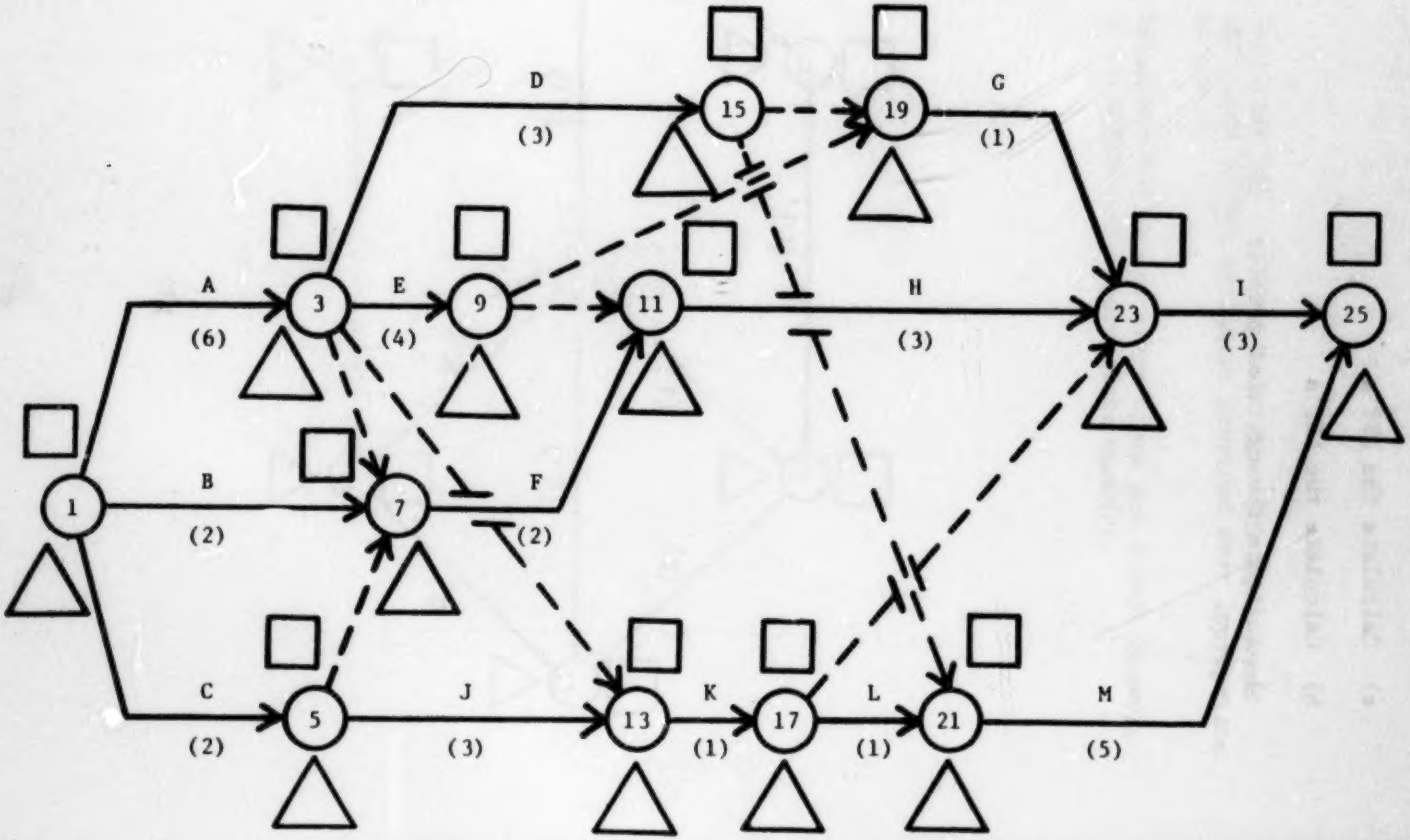
For the following problems

a) Calculate the EET's

b) Calculate the LET's

c) Indicate the critical path(s)

STUDENT PRACTICAL EXERCISE III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17
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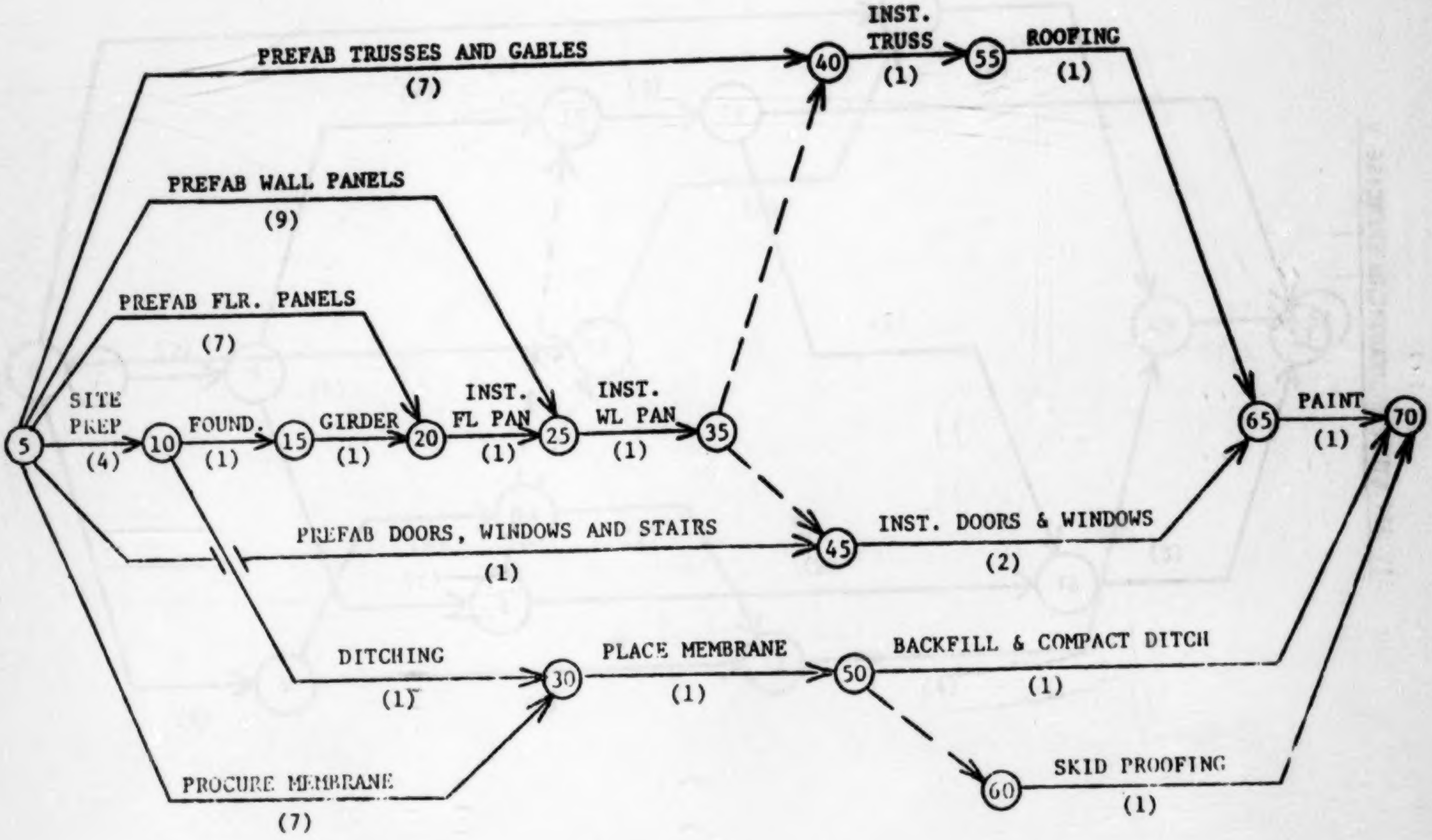
21
23
25
A
(6)
B
(2)
C
(2)
D
(3)
E
(4)
F
(2)
G
(1)
H
(3)
I
(3)
J
(3)
K
(1)
L
(1)
M
(5)

STUDENT PRACTICAL EXERCISE IV

TRAINING BUILDING


PREFAB TRUSSES AND GABLES
(7)
INST. TRUSS
(1)
ROOFING
(1)
PREFAB WALL PANELS
(9)
PREFAB FLR. PANELS
(7)
SITE PREP
(4)
FOUND.
(1)
GIRDER
(1)
INST. FL PAN
(1)
INST. WL PAN
(1)
PAINT
(1)
PREFAB DOORS, WINDOWS AND STAIRS
(1)
INST. DOORS & WINDOWS
(2)
DITCHING
(1)
PLACE MEMBRANE
(1)
BACKFILL & COMPACT DITCH
(1)
PROCURE MEMBRANE
(7)
SKID PROOFING
(1)
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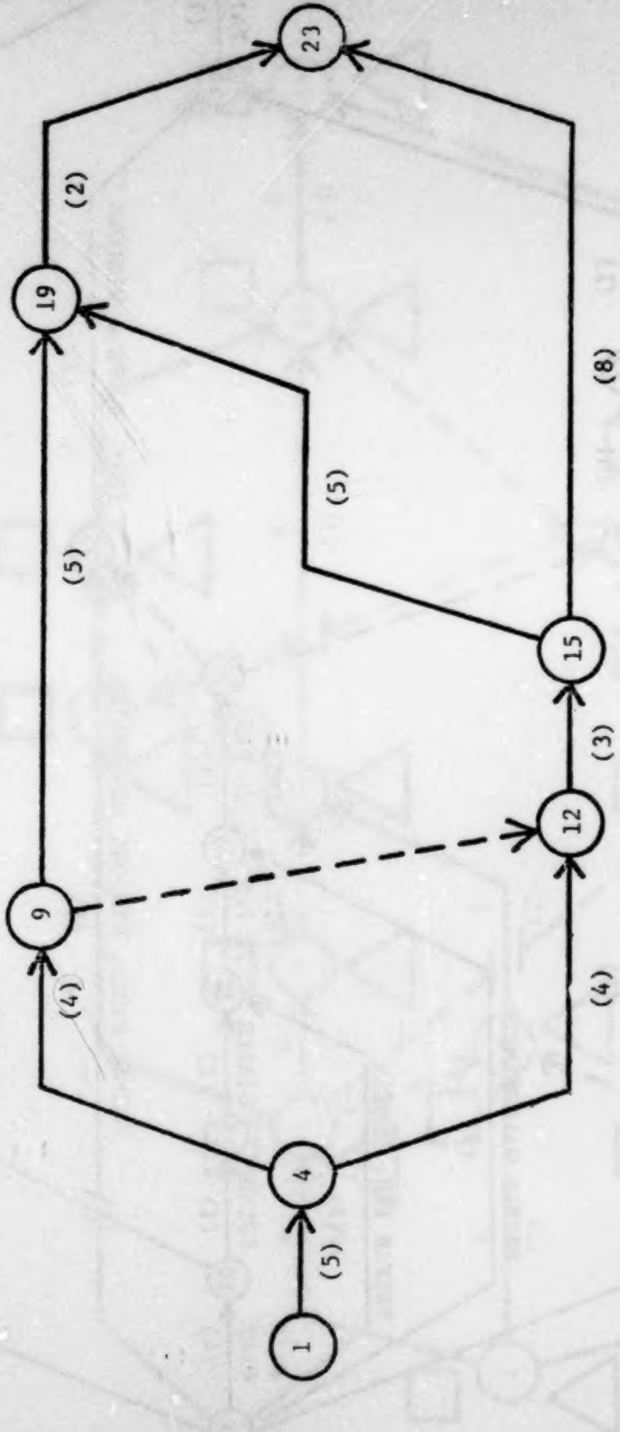
50
55
60
65
70

STUDENT PRACTICAL EXERCISE V


1
(5)
4
(4)
(4)
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(3)
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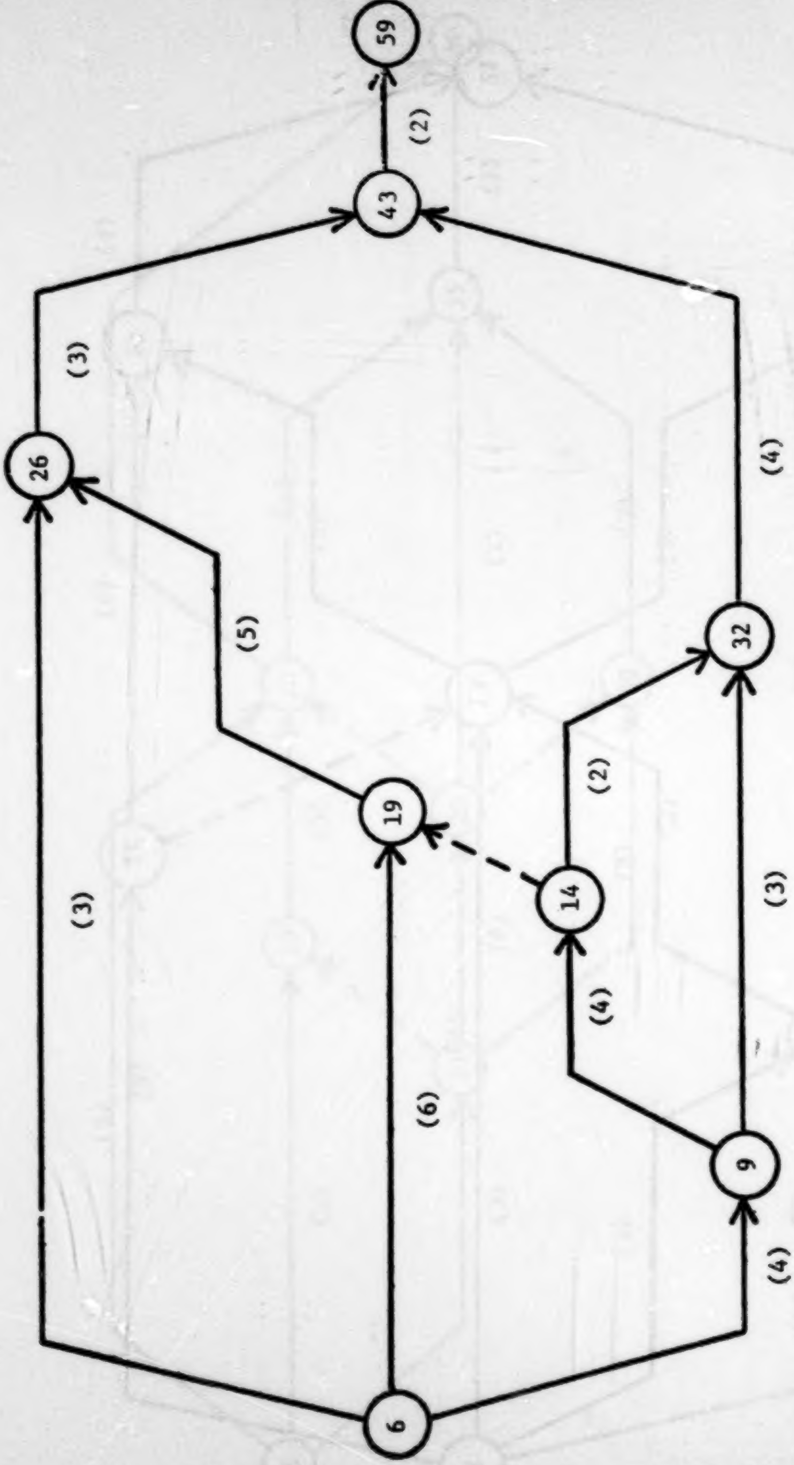
(5)
(5)
19
(8)
(2)
23

STUDENT PRACTICAL EXERCISE VI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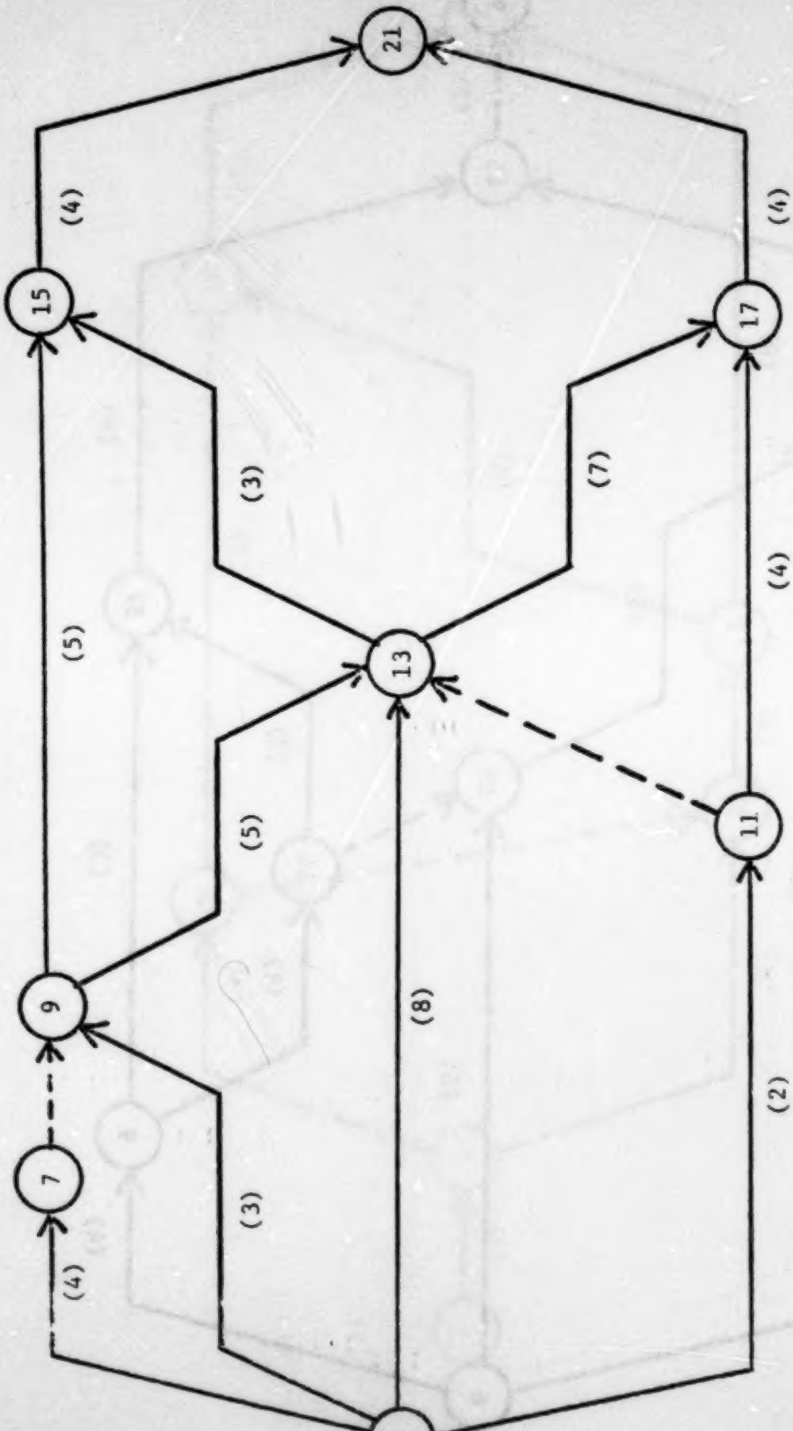
(2)
43
(3)
26
(4)
(5)
32
(2)
19
14
(3)
(3)
(4)
(6)
9
(4)
6

STUDENT PRACTICAL EXERCISE VII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21
(4)
(3)
(8)
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(5)
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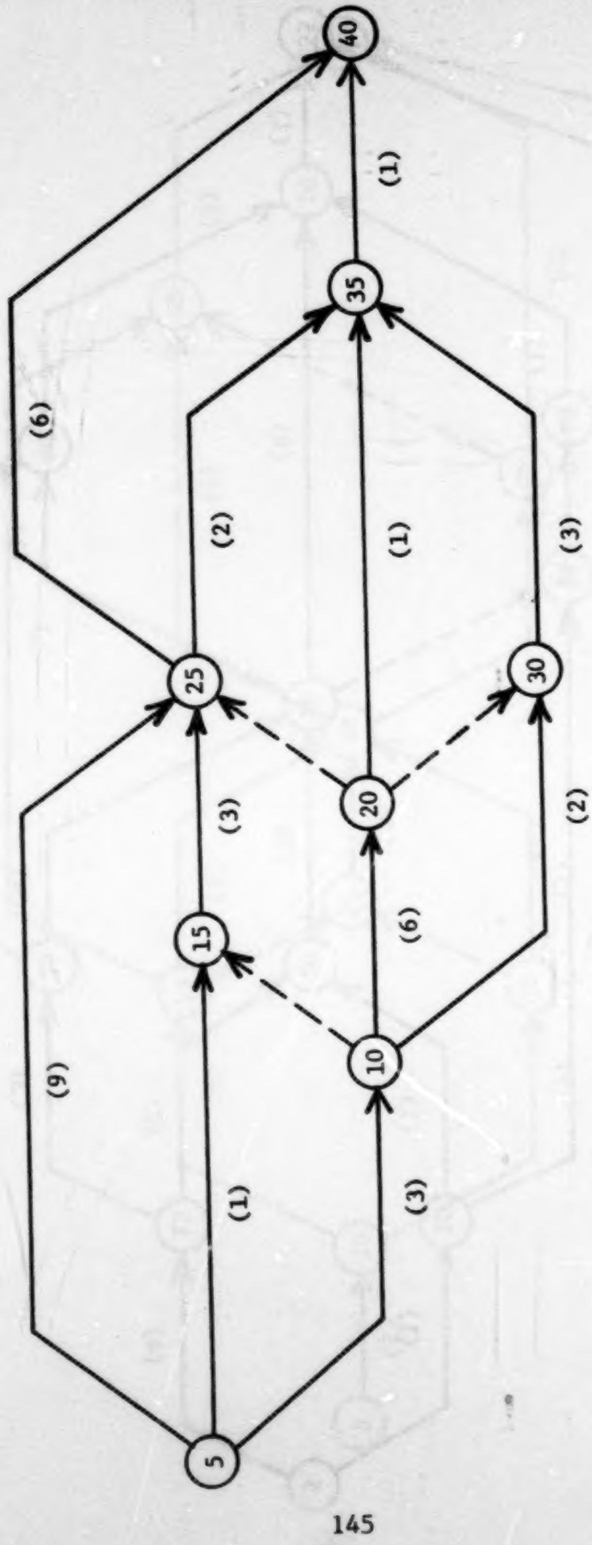
(4)
(3)
(7)
(4)
(4)

STUDENT PRACTICAL EXERCISE VIII



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10
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30
35
40
(9)
(1)
(3)
(6)
(3)
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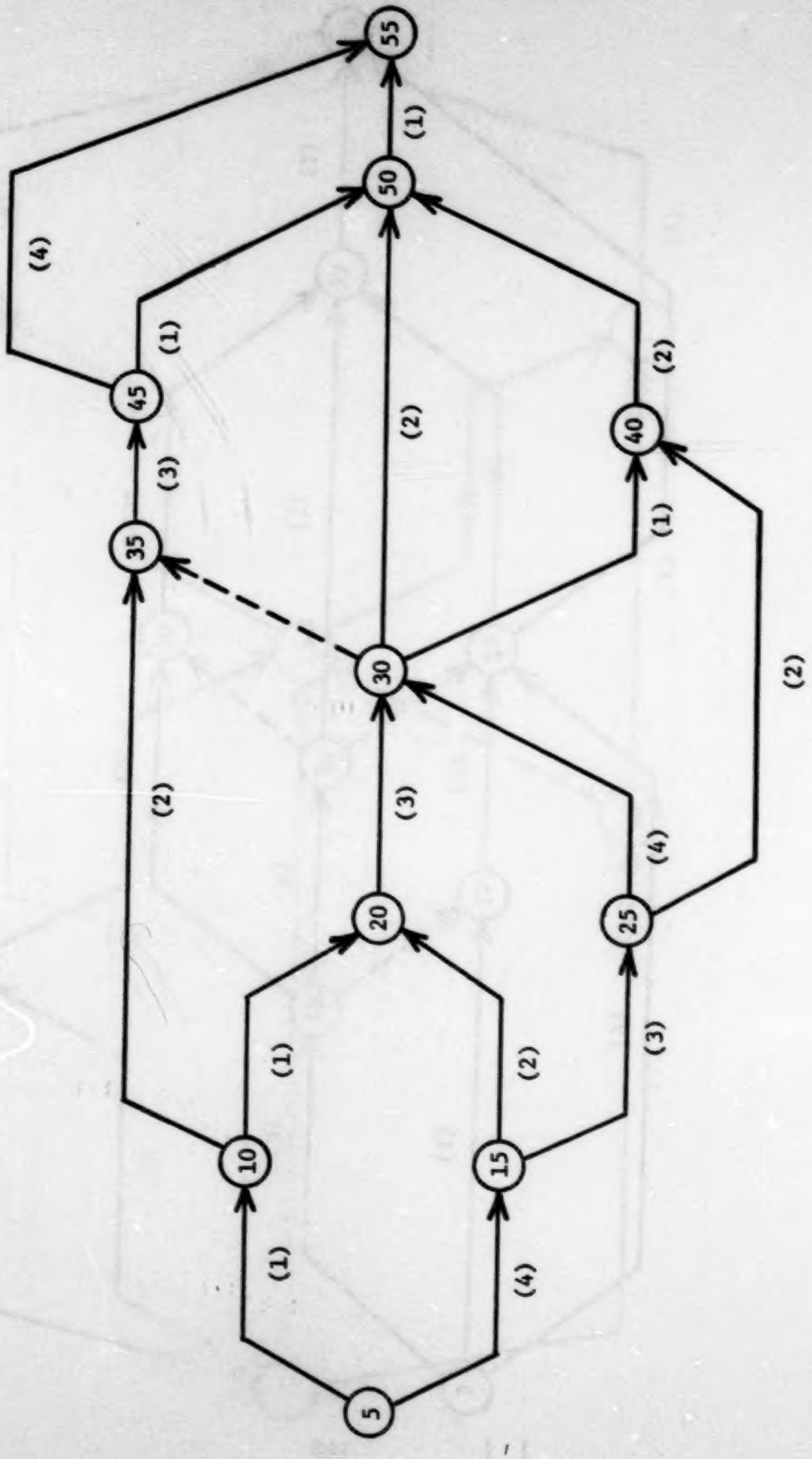
(6)
(2)
(1)
(3)
(1)

STUDENT PRACTICAL EXERCISE IX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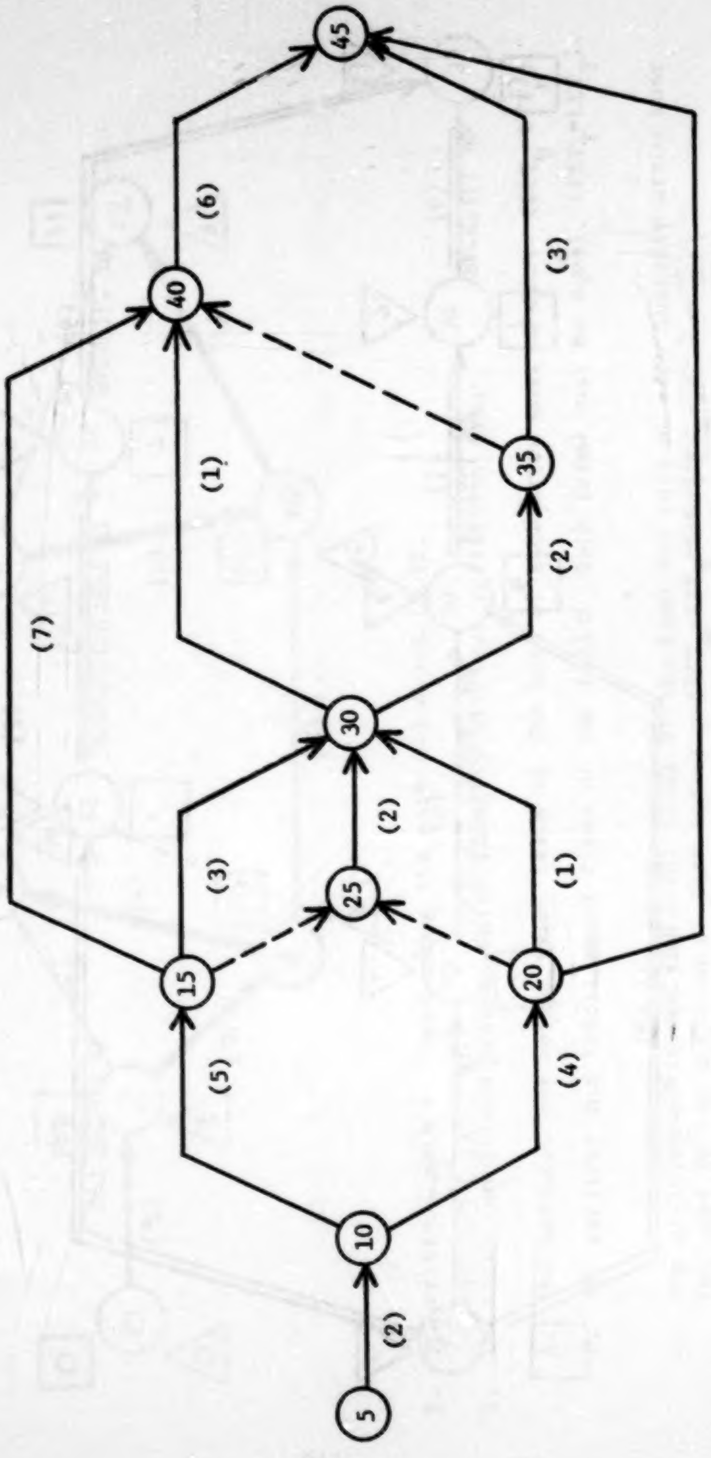
50
55
(1)
(4)
(1)
(2)
(2)
(3)
(3)
(4)
(2)
(1)
(2)
(3)
(1)
(2)
(2)
(1)
(4)
(1)

STUDENT PRACTICAL EXERCISE X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(2)
10
(5)
(4)
15
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(7)
(3)
(2)
(1)
(7)
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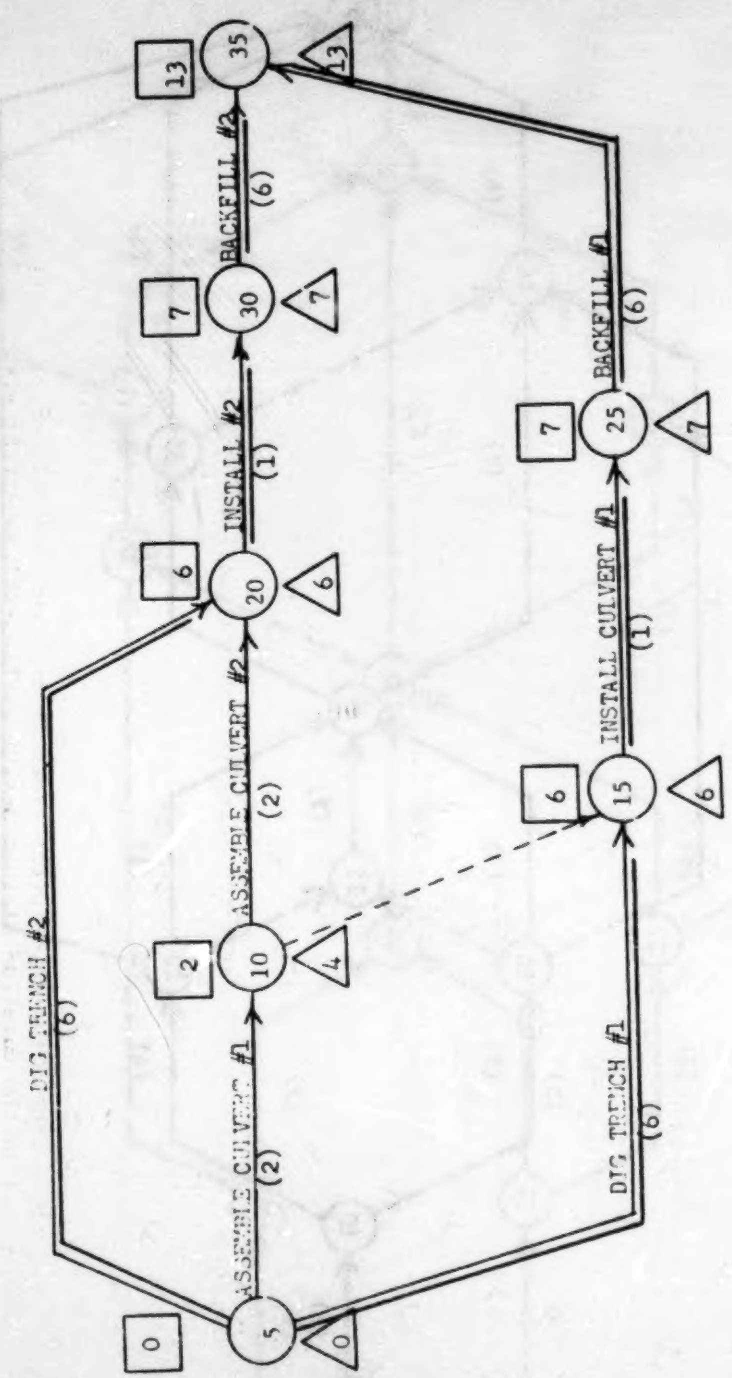
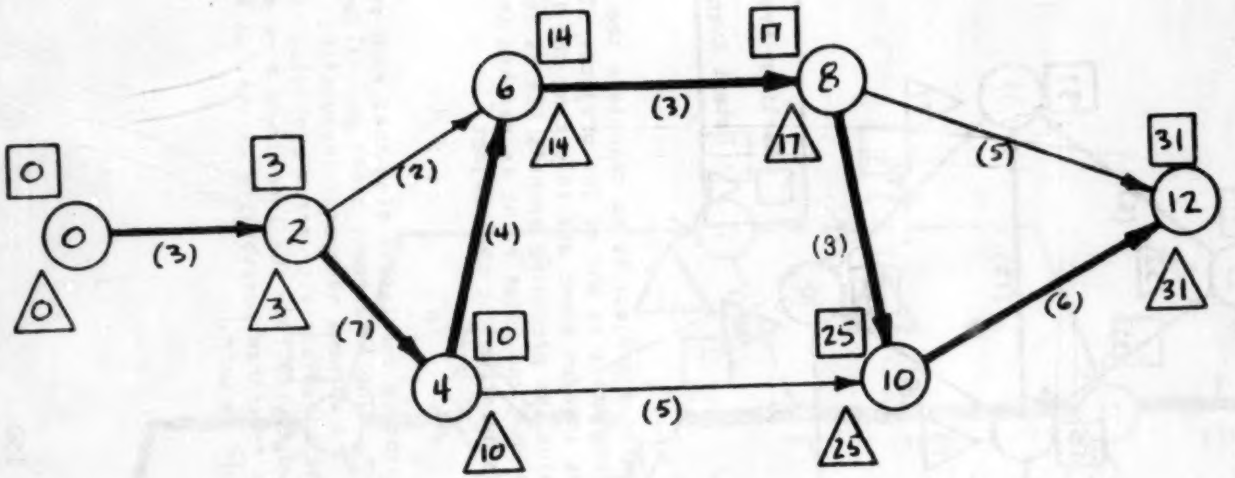
30
(1)
(2)
35
40
(6)
(3)
45

SOLUTION TO TIME ANALYSIS PE


DIG TRENCH #2
(6)
ASSEMBLE CULVERT #1
(2)
ASSEMBLE CULVERT #2
(2)
INSTALL #2
(1)
BACKFILL #2
(6)
DIG TRENCH #1
(6)
INSTALL CULVERT #1
(1)
BACKFILL #1
(6)
5
10
15
20
25
30
35
0
2
6
6
7
7
13
0
4
6
6
7
7
13

A SOLUTION FOR STUDENT PRACTICAL EXERCISE 1



1. The critical path is found along the path 0-2-4-6-8-10-12.

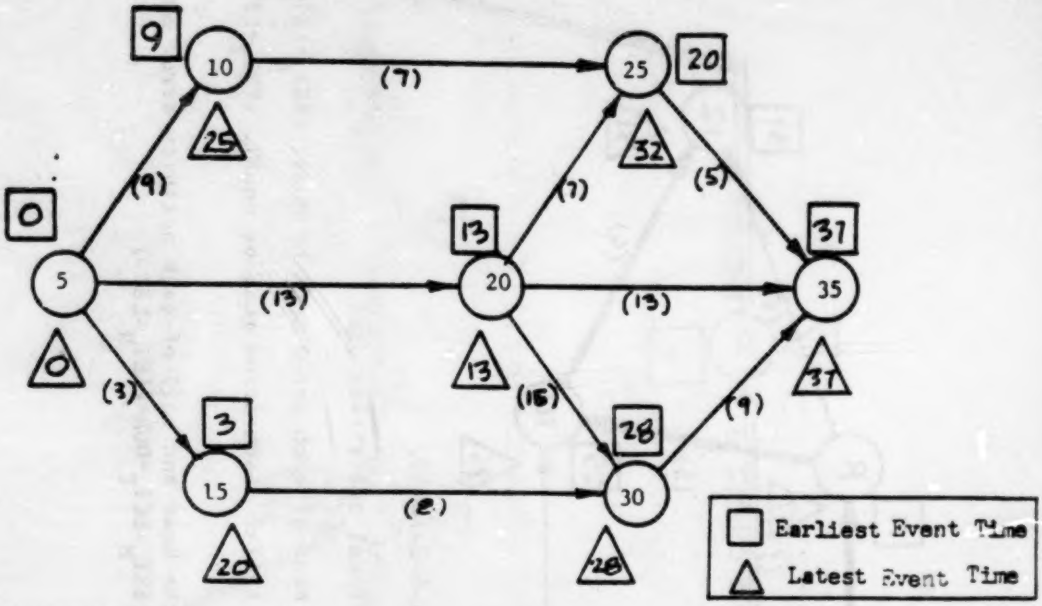
2. The three conditions present which identify critical activities are:

   A. The earliest and latest event times at the head of each arrow must be equal. ($EET_H = LET_H$)

   B. The earliest and latest event times at the tail of each arrow must be equal. ($EET_T = LET_T$).

   C. The difference between the event times at the head and tail of each activity arrow must be equal to the duration of that activity ($EET_H - EET_T = DUR = (LET_H - LET$)

A SOLUTION TO STUDENT PRACTICAL EXERCISE II



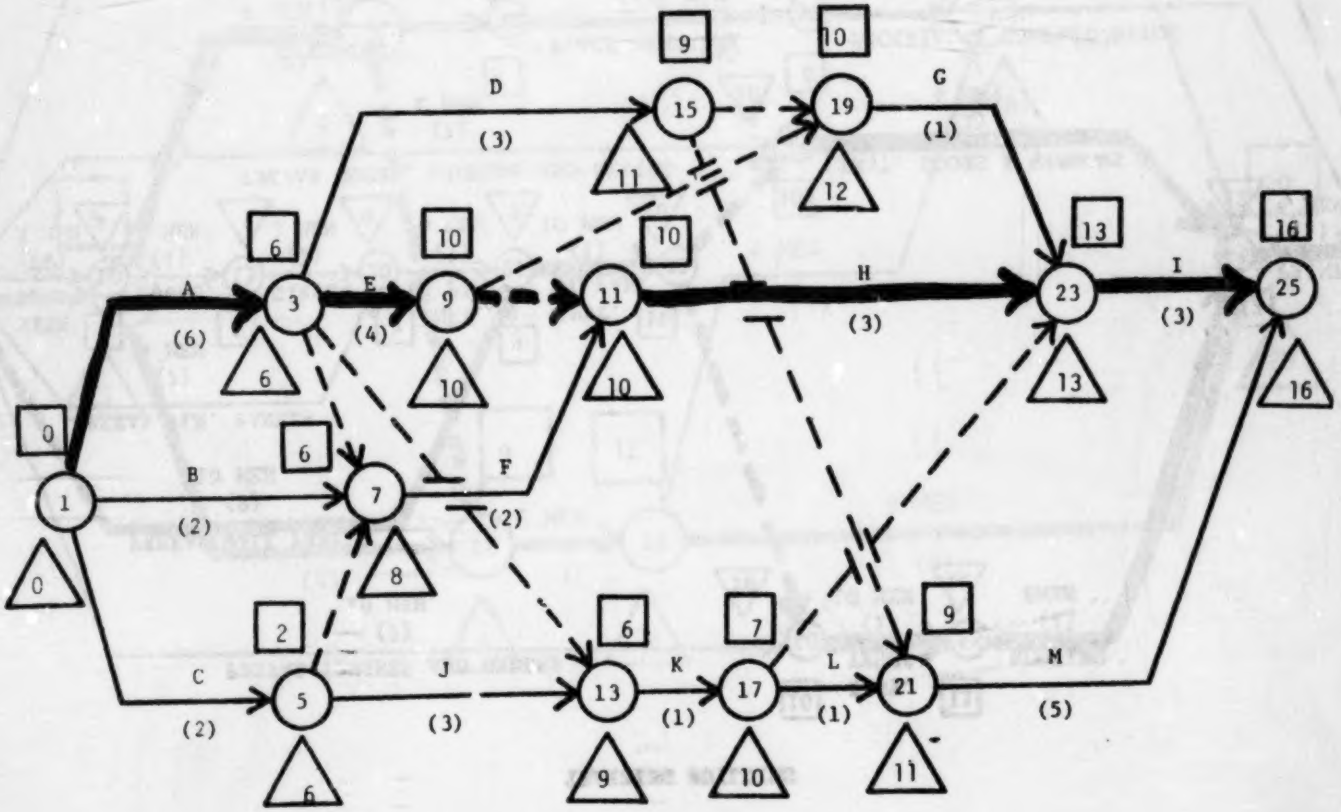
REQUIREMENT A:

The way to calculate the duration of a project is to calculate the earliest event time for each event from start to end of the project. This is done by checking each path leading into an event and selecting the largest sum of the preceding task duration plus the preceding event's EET as the earliest event time for that event. When the final event is reached the final earliest event time will be the duration for the project.

REQUIREMENT B:

The latest event time for each event is the latest time that each event must occur without delaying the project. The late event times are calculated by starting at the final event and working backwards through the network. Late event times at the tail of an activity arrow are calculated by subtracting the duration for that activity from the late event time at the head of the activity arrow. When more than possibility exists, as in events 0 & 6 above, the smallest result is used.

A SOLUTION TO STUDENT PRACTICAL EXERCISE III



1
0
0
A
(6)
B
(2)
C
(2)
3
6
6
5
2
6
7
6
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D
(3)
E
(4)
F
(2)
J
(3)
9
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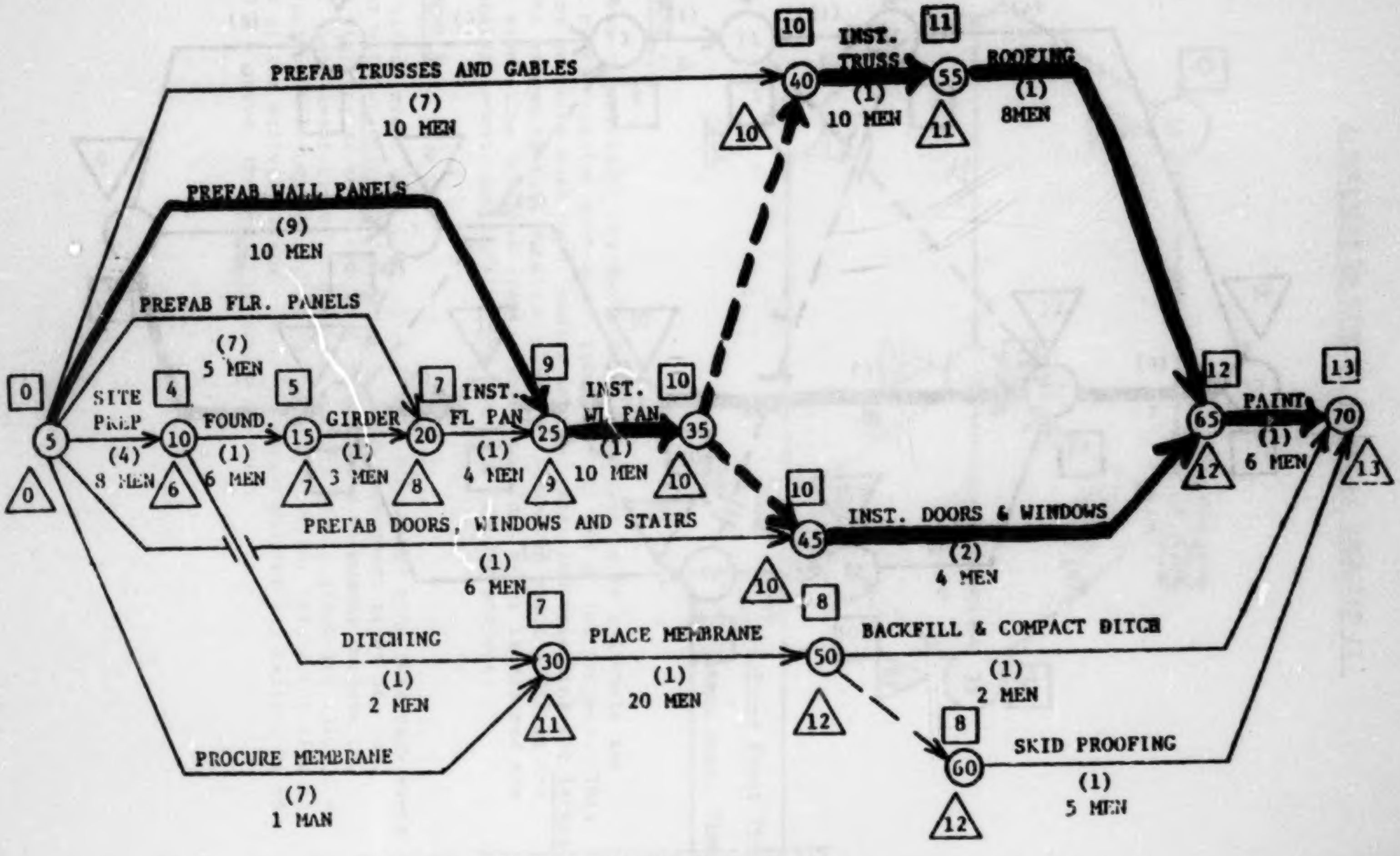
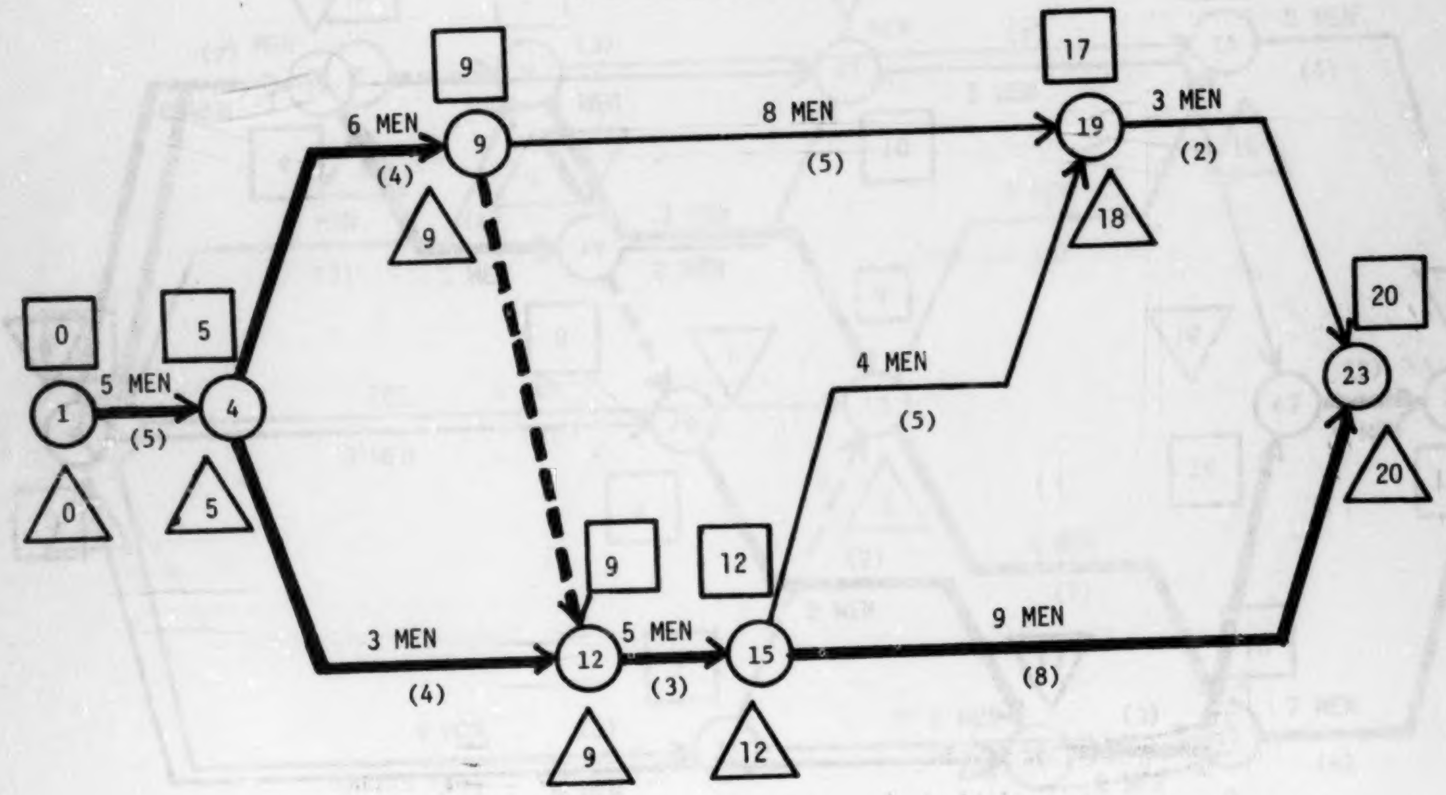
10
11
10
10
13
6
9
15
9
11
19
10
12
G
(1)
H
(3)
K
(1)
17
7
10
L
(1)
21
9
11
M
(5)
23
13
13
I
(3)
25
16
16

SOLUTION TO STUDENT PRACTICAL EXERCISE IV

TRAINING BUILDING


0
5
0
SITE PREP
(4)
8 MEN
4
10
6
FOUND.
(1)
6 MEN
5
15
7
GIRDER
(1)
3 MEN
7
20
8
INST. FL PAN
(1)
4 MEN
9
25
9
INST. WL PAN
(1)
10 MEN
10
35
10
PREFAB TRUSSES AND GABLES
(7)
10 MEN
PREFAB WALL PANELS
(9)
10 MEN
PREFAB FLR. PANELS
(7)
5 MEN
PREFAB DOORS, WINDOWS AND STAIRS
(1)
6 MEN
DITCHING
(1)
2 MEN
PROCURE MEMBRANE
(7)
1 MAN
10
40
10
INST. TRUSS
(1)
10 MEN
11
55
11
ROOFING
(1)
8MEN
10
45
10
INST. DOORS & WINDOWS
(2)
4 MEN
7
30
11
PLACE MEMBRANE
(1)
20 MEN
8
50
12
BACKFILL & COMPACT DITCH
(1)
2 MEN
8
60
12
SKID PROOFING
(1)
5 MEN
12
65
12
PAINT
(1)
6 MEN
13
70
13

SOLUTION PE V


0
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(5)
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9
3 MEN
(4)
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9
5 MEN
(3)
12
15
12
8 MEN
(5)
17
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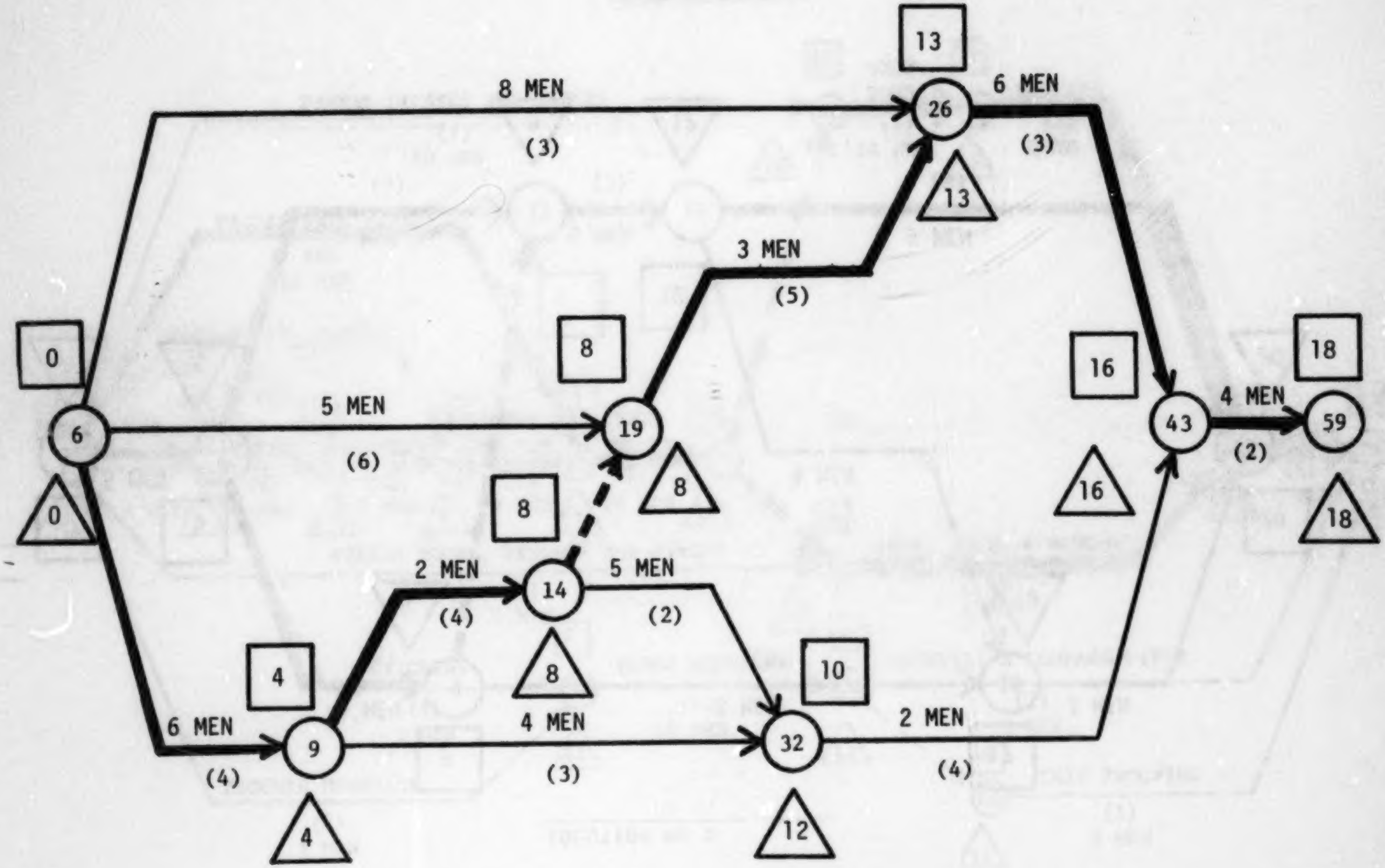
18
4 MEN
(5)
3 MEN
(2)
9 MEN
(8)
20
23
20

SOLUTION PE VI



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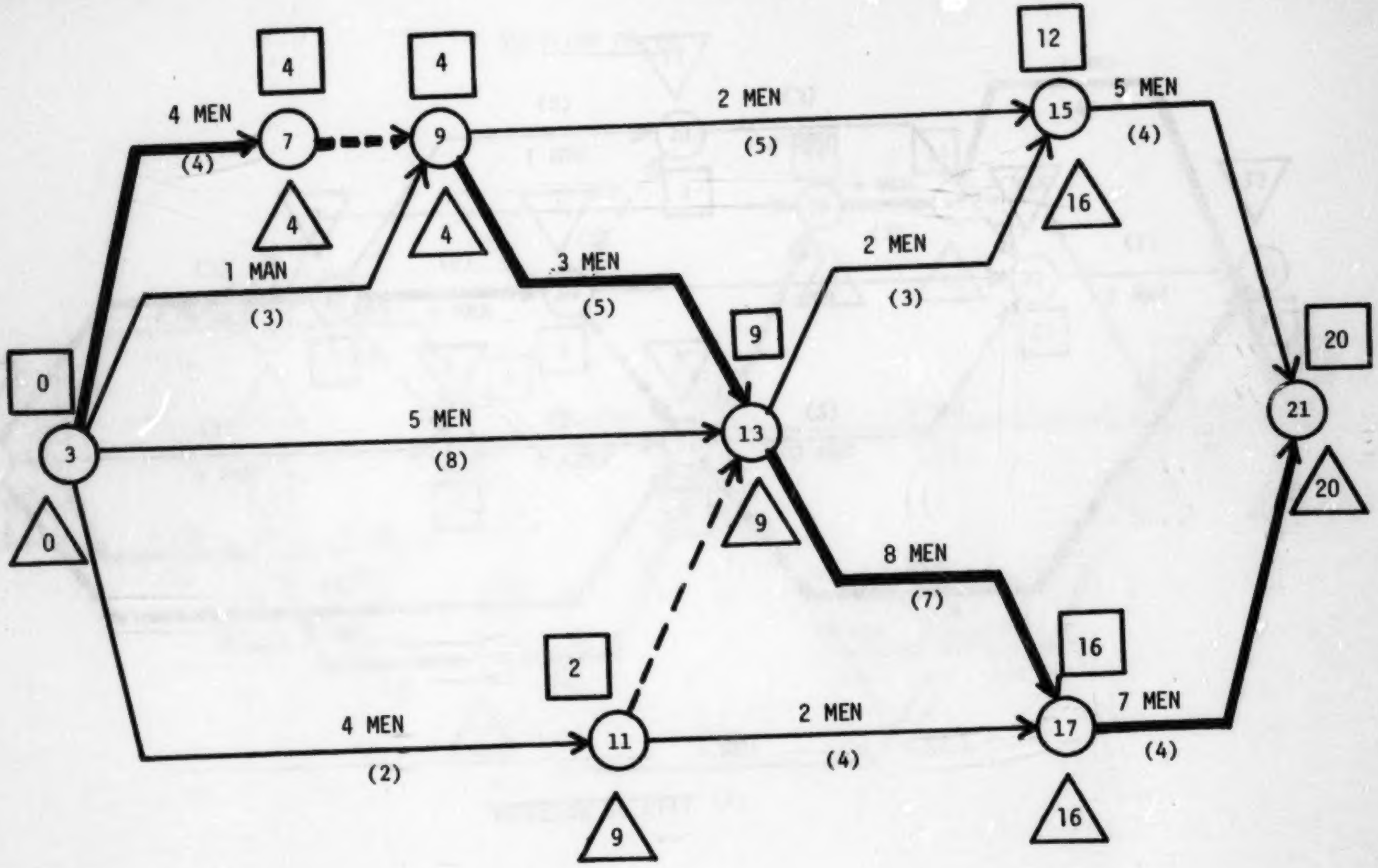
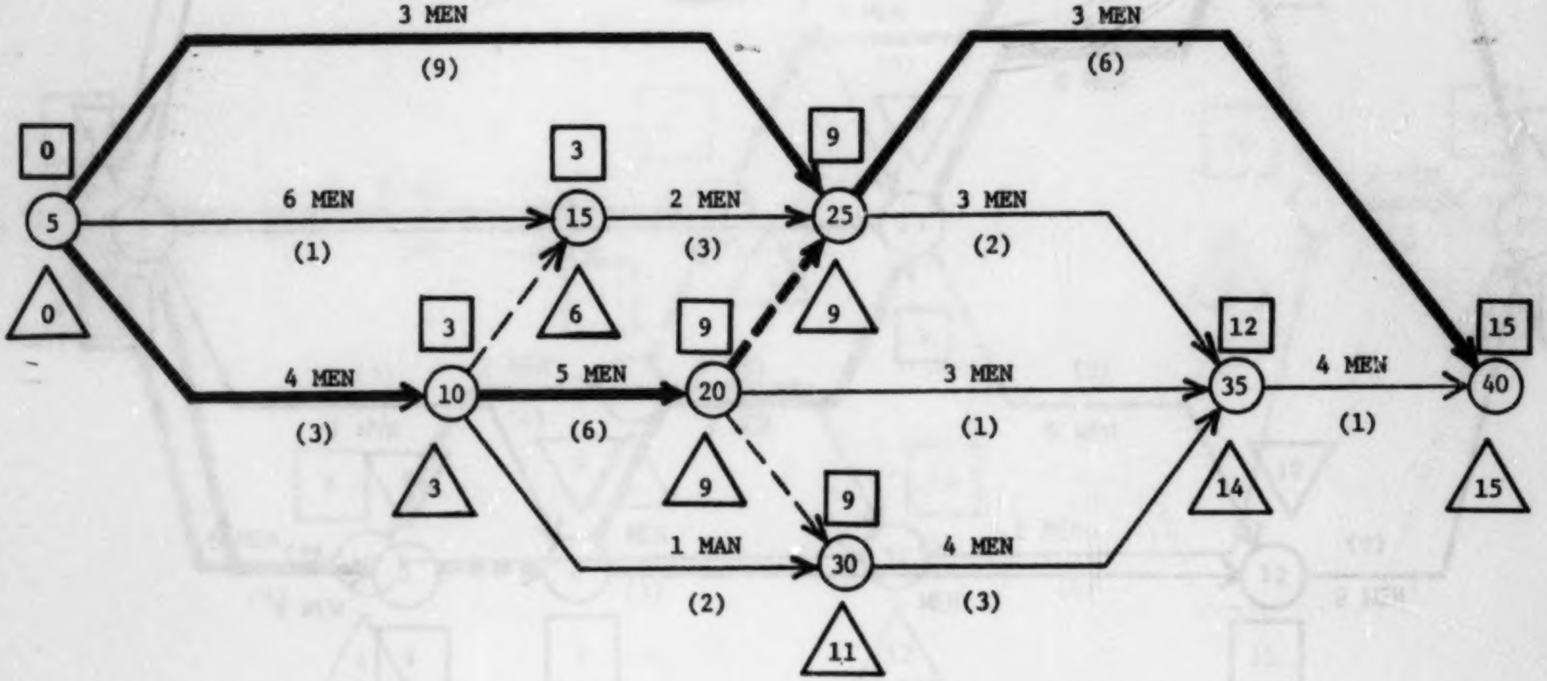
8 MEN
(3)
13
26
13
6 MEN
(3)
5 MEN
(6)
8
19
8
3 MEN
(5)
16
43
16
4 MEN
(2)
18
59
18
6 MEN
(4)
4
9
4
2 MEN
(4)
8
14
8
5 MEN
(2)
4 MEN
(3)
10
32
12
2 MEN
(4)

SOLUTION PE VII


3
0
0
4 MEN
(4)
7
4
4
1 MAN
(3)
9
4
4
5 MEN
(8)
4 MEN
(2)
11
2
9
2 MEN
(5)
3 MEN
(5)
13
9
9
2 MEN
(4)
2 MEN
(3)
8 MEN
(7)
15
12
16
17
16
16
5 MEN
(4)
7 MEN
(4)
21
20
20

SOLUTION PE VIII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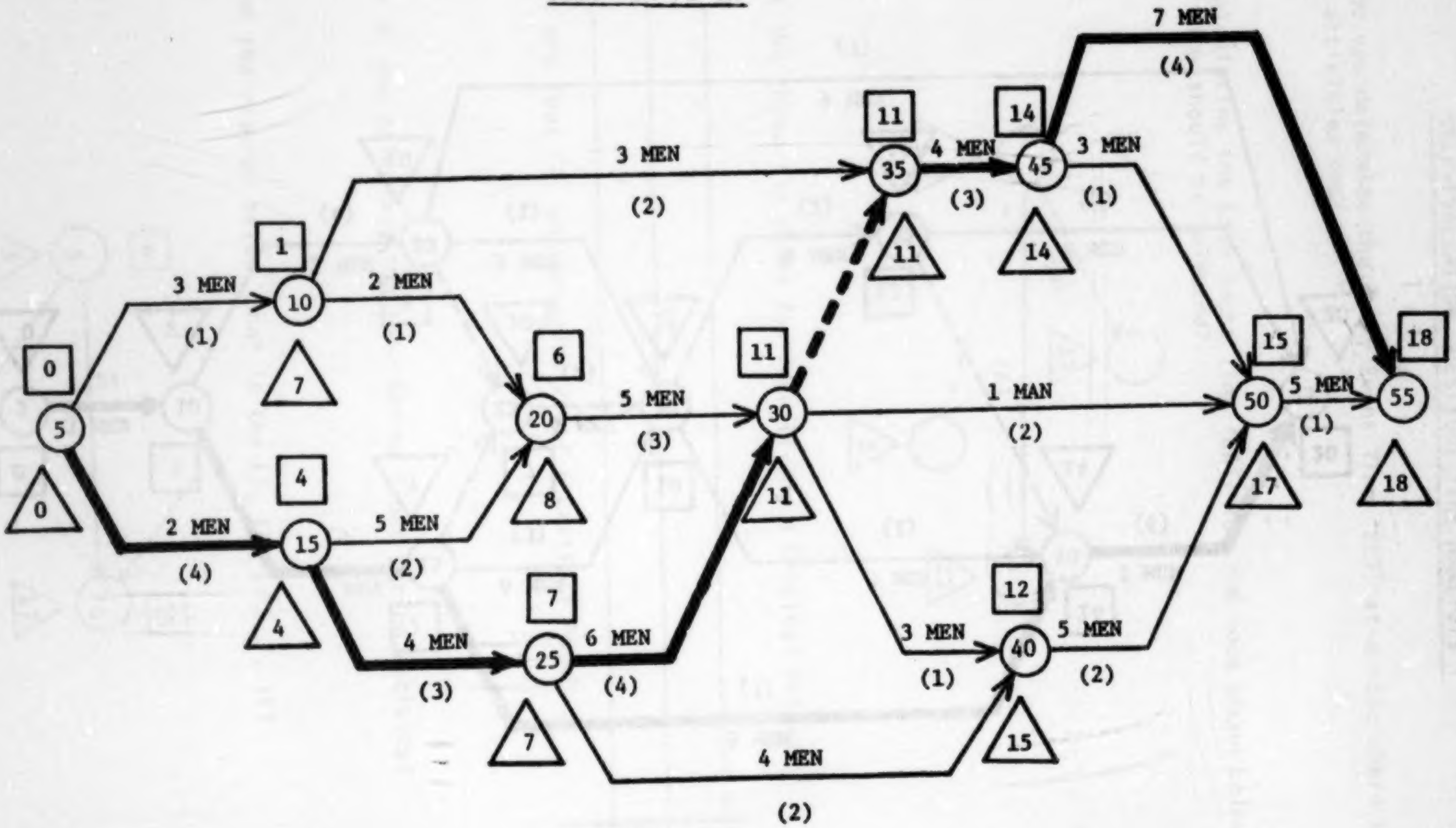
(9)
6 MEN
(1)
4 MEN
(3)
3
15
6
3
10
3
2 MEN
(3)
5 MEN
(6)
1 MAN
(2)
9
20
9
9
25
9
9
30
11
3 MEN
(6)
3 MEN
(2)
3 MEN
(1)
4 MEN
(3)
12
35
14
4 MEN
(1)
15
40
15

SOLUTION PE IX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(1)
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(4)
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4
2 MEN
(1)
5 MEN
(2)
4 MEN
(3)
6
20
8
7
25
7
5 MEN
(3)
6 MEN
(4)
11
30
11
3 MEN
(2)
11
35
11
4 MEN
(3)
14
45
14
7 MEN
(4)
3 MEN
(1)
1 MAN
(2)
3 MEN
(1)
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4 MEN
(2)
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(2)
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17
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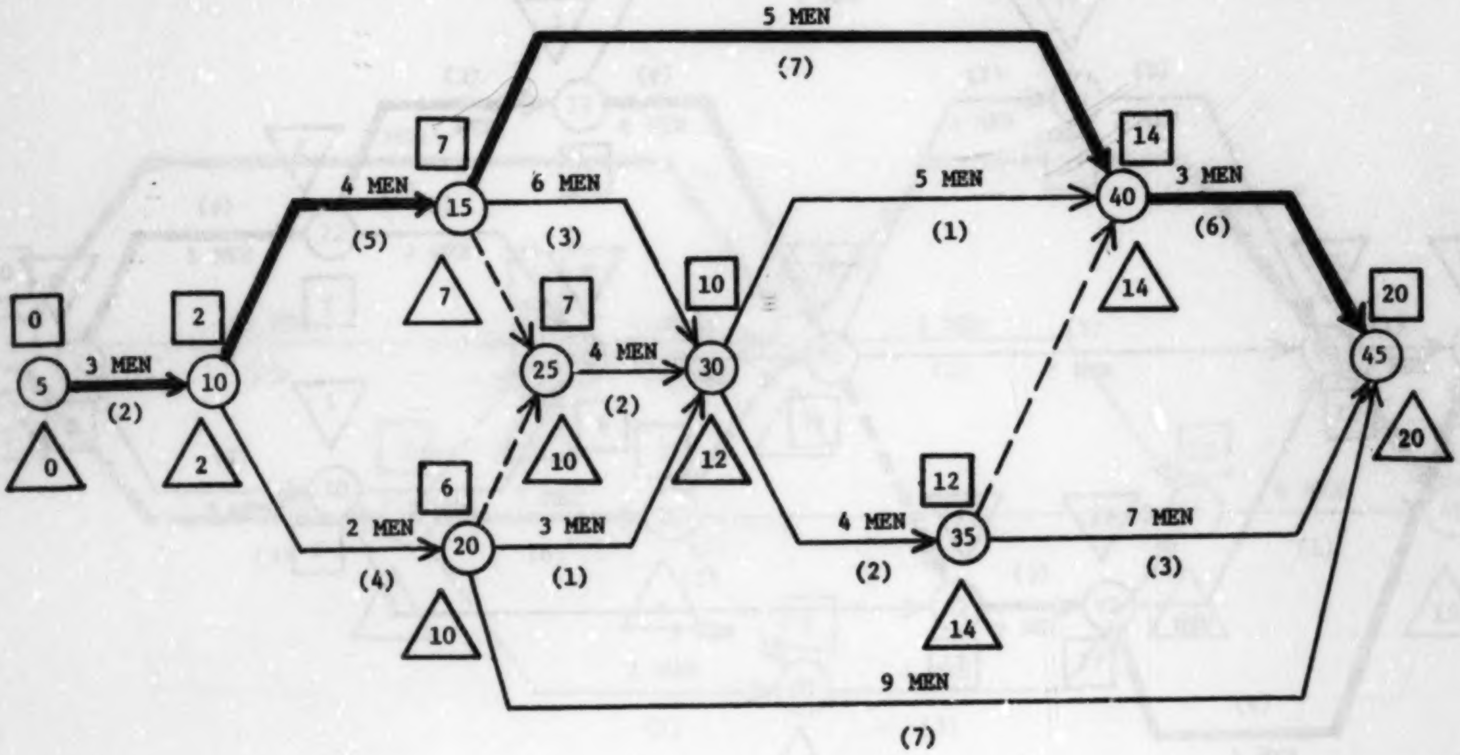
(1)
18
55
18

SOLUTION PE X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(2)
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(5)
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2 MEN
(4)
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10
6 MEN
(3)
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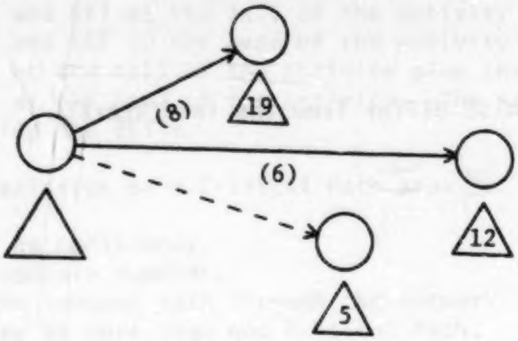
4 MEN
(2)
3 MEN
(1)
30
10
12
5 MEN
(7)
5 MEN
(1)
4 MEN
(2)
35
12
14
40
14
14
3 MEN
(6)
7 MEN
(3)
9 MEN
(7)
45
20
20

SELF-EVALUATION QUESTIONS TIME ANALYSIS I

1. How do you determine the Early Event Time (EET) at a node where two or more activities end?

2. In calculating the Late Event Time (LET) for the node shown below, what time should be selected?



3. List the three (3) rules for identifying a Critical Activity.

a. ____________________

b. ____________________

c. ____________________

4. What are four (4) characteristics of a Critical Path?

a.

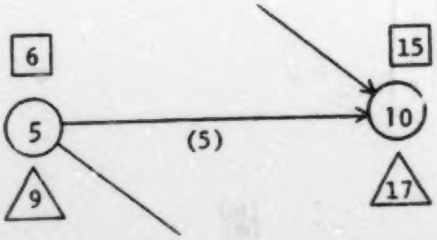
b.

c.

d.

5. How do you calculate the Interfering Float for an activity?

6. From the diagram below, what is the ES, EF, LS, LF, IF?



SELF-EVALUATION QUESTIONS TIME ANALYSIS II

1. What management information do you have available after completing the time analysis to use to answer questions about the project?

2. How does the early finish differ from the late start?

3. Discuss the Critical Path as a management tool.

SOLUTIONS FOR SELF-EVALUATION TIME ANALYSIS I

1. Always choose the largest or longer time, since the event cannot occur until all the activities ending at the node are complete.

2. The answer is 5. Even though the smallest number is along the dummy arrow that is the correct answer. Remember that the LET is the smallest (shortest) time of all the activities starting at the node.

3. a. The LET and EET at the tail of the activity must be equal.
   b. The LET and EET at the head of the activity must be equal.
   c. The LET at the tail of the activity plus the duration must equal the LET at the head of the activity. The same calculations can be done using the EET's.

4. The characteristics of a Critical Path are:

   a. It must be continuous.
   b. It can contain dummies.
   c. It is the longest path through the network.
   d. There may be more than one Critical Path.

5. Interfering Float can be calculated by taking the difference between the EET and the LET at the head of an activity.

6. $ES = EET_t$ plus one = 7.

   $EF = EET_t + \text{Duration} = 11$

   $LS = LET_h - \text{Duration} = 17-5 = 12$

   $LF = LET_h = 17$

   $IF = LET_h - EET_h = 17-15 = 2$

LESSON: Early Start Scheduling

OBJECTIVE: The student, given TM 5-333 and a logic network, will be able to develop an early start schedule showing the time frame and the free and interfering float for each activity. The student will be able to use the schedule to analyze the resources needed during any time period and the effects of changes or delays on the project.

REFERENCES: TM 5-333, para 2-10 and 2-11.
Programmed Text: CPM Scheduling
Engineer Management Review Problems Student Workbook

STUDENT NOTES

SCHEDULING:

The planning phase of management is complete and now we will begin the scheduling phase. The schedule is one of the most useful tools in project management. It provides a time picture of the plan. All the information determined in the logic, estimating and time analysis classes will be plotted on the schedule. The result is a time scaled portrayal of the planned work and the resources required during any time period. The schedule is also the best and fastest means of evaluating the effects of changes and delays on the project.

SCHEDULING STEPS:

There are five basic steps in constructing a schedule from a logic network.

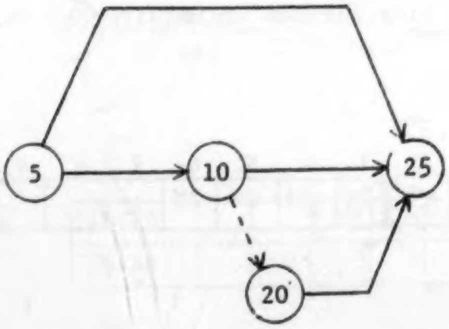
1. LIST THE ACTIVITIES:

   a. The network activities are listed on the schedule in ascending order, starting with the smallest beginning event node. Activities that begin at the same event node are listed together in ascending ending numerical order. Omit dummy activities and only schedule work activities. This will reduce the size of the schedule since a dummy activity takes zero time and consumes no resources, it would be a blank line on the schedule.

   b. A column for activity descriptions can be added beside the activity number column. Many people find that a short description makes the schedule clearer. For the teaching problems in the workbook, the description column has been omitted.

   c. To maintain the original logic of the network, show the dummy activities in parenthesis after the event(s) they follow. The following example indicates how dummy activities and regular activities would be listed on the schedule:

Network

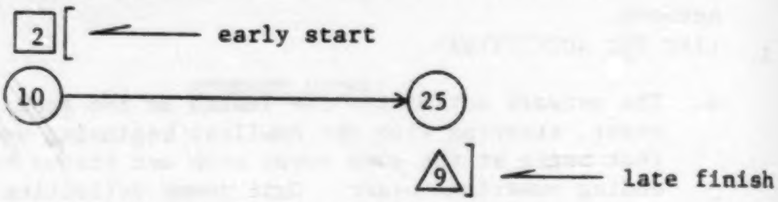


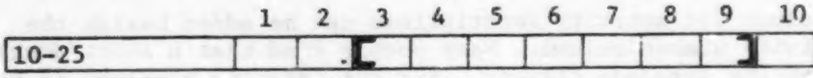
Schedule Activity List

5-10(20)
5-25
10-25
20-25

2. MARK THE TIME FRAME:

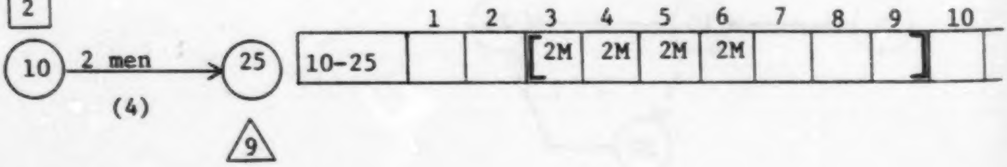
Using brackets, [ ], mark the early start and late finish time frames for each activity. This time frame gives us a range in which the activity may be accomplished and still complete the project on time. REMEMBER! The early start time is the early event time at the tail of the activity arrow plus one (ES+1). This means that the activity being scheduled can start the time period after the one listed in the square at the tail of the activity arrow. The late finish time is the late event time in the triangle at the head of the activity arrow.





3. SCHEDULE THE RESOURCES:

There are many types of schedules but the one that gives the military manager the greatest flexibility is the early start schedule, which is the type we will develop. The time and resources required for each activity can be found on the activity estimate sheet and on the logic network. The resources are listed on the early start schedule as far to the left of the time frame as possible and for as many time periods as required by the estimated duration.



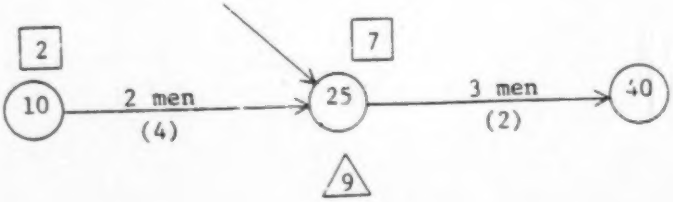
4. IDENTIFY THE FLOAT:

a. Once the resources have been scheduled for the estimated duration, there will be a difference between the early finish and late finish times for non-critical activities. This extra time is called float and can be further divided into two distinct types of float, FREE and INTERFERING.

b. Interfering float (IF) occurs when an activity, moving within its time frame, interferes with the early start of a DEPENDENT activity. In other words, if by moving into a time period, the completion of an activity overlaps the start of an activity that cannot begin until the first activity is complete, then that time period of float is said to be interfering. An "X" is used to indicate interfering float. (HINT: Once one time periof of "IF" is determined, all time periods to the right, within the time frame, will be interfering). The "X's" act as warning flags to the manager and tell him that if an activity is delayed into a time period filled with an X then other dependent activities will be affected.

c. The interfering float can also be determined mathematically by subtracting the Early Event Time at the head of the activity (EET_H) from the Late Event Time at the head of the activity (LET_H). There is one exception to this technique and it is explained on the back of the workbook.

d. The remaining time periods, which are not filled by X's constitute the FREE float. These time periods are important to the manager because they indicate the areas where he can delay activities with a minimal effect on the project.



	1	2	3	4	5	6	7	8	9	10	11
10-25			[2M	2M	2M	2M		X	X		
25-40								[3M	3M		

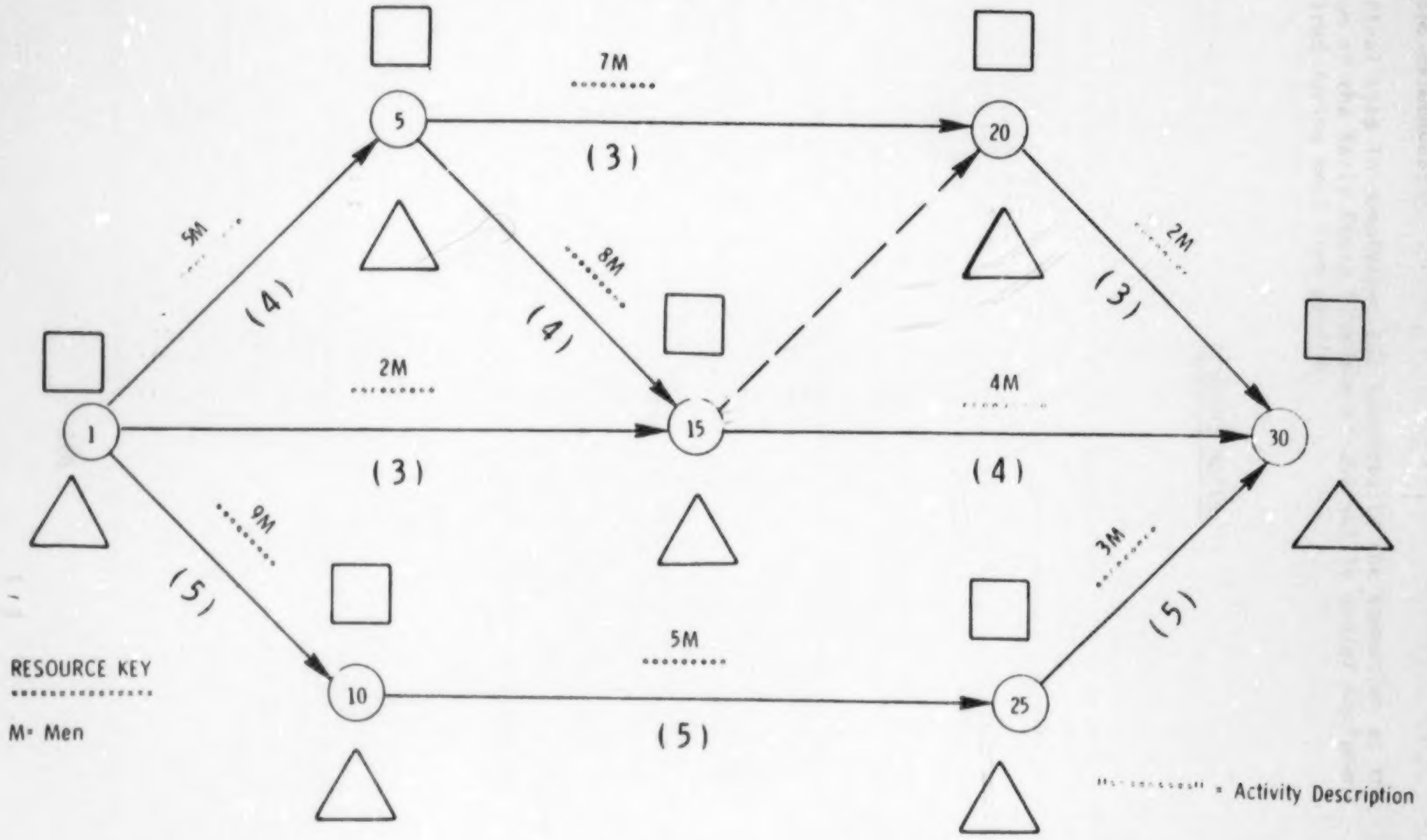
5. SUM THE RESOURCES:

The final step in completing the schedule is the summation at the bottom of the Early Start Schedule of the skills and/or equipment required during each time period.

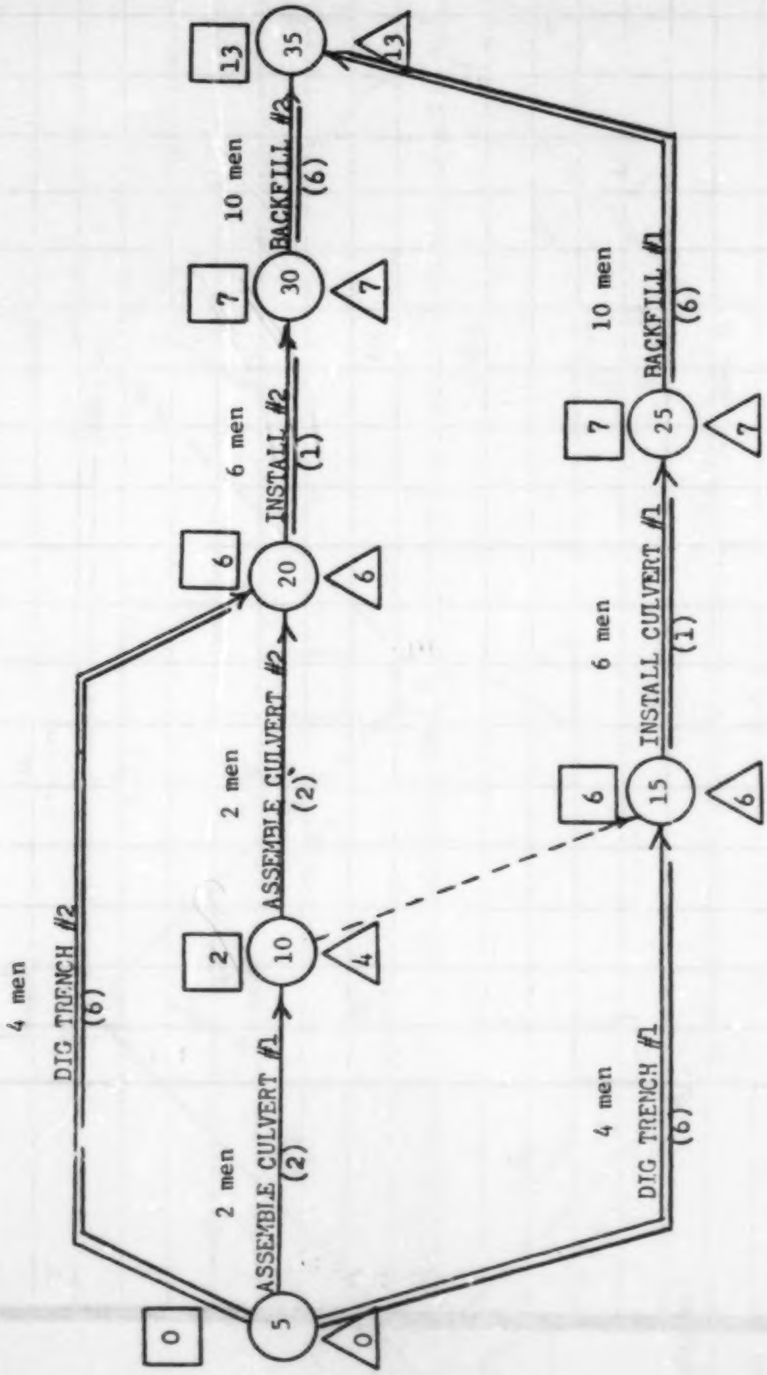
STUDENT NOTES

STUDENT NOTES

LEAD THROUGH PRACTICAL EXERCISE


1
5
10
15
20
25
30
5M
(4)
2M
(3)
9M
(5)
7M
(3)
8M
(4)
5M
(5)
2M
(3)
4M
(4)
3M
(5)
RESOURCE KEY
M= Men
"..........." = Activity Description

NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20



0
5
0
2 men
ASSEMBLE CULVERT #1
(2)
2
10
4
2 men
ASSEMBLE CULVERT #2
(2)
6
20
6
6 men
INSTALL #2
(1)
7
30
7
10 men
BACKFILL #3
(6)
13
35
13
4 men
DIG TRENCH #2
(6)
4 men
DIG TRENCH #1
(6)
6
15
6
6 men
INSTALL CULVERT #1
(1)
7
25
7
10 men
BACKFILL #1
(6)

SCHEDULING PE

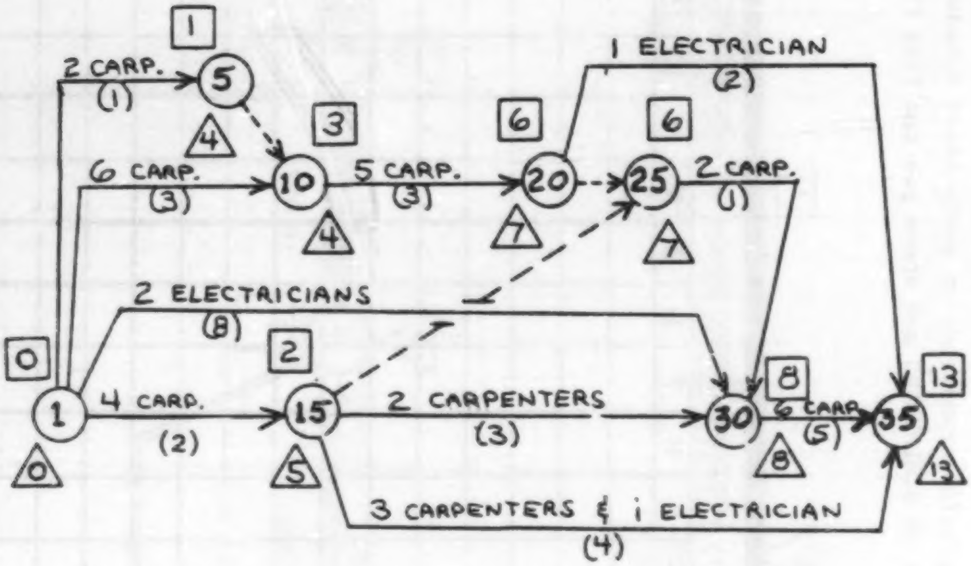
Using the completed Network and blank schedule below, construct an early start schedule for the Two Culvert Problem. Remember the FIVE STEPS IN SCHEDULING and where you can find the resources required for each activity.

NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

STUDENT PRACTICAL EXERCISE I

Situation: Given network as shown below with durations in days and resource requirements shown for each activity.

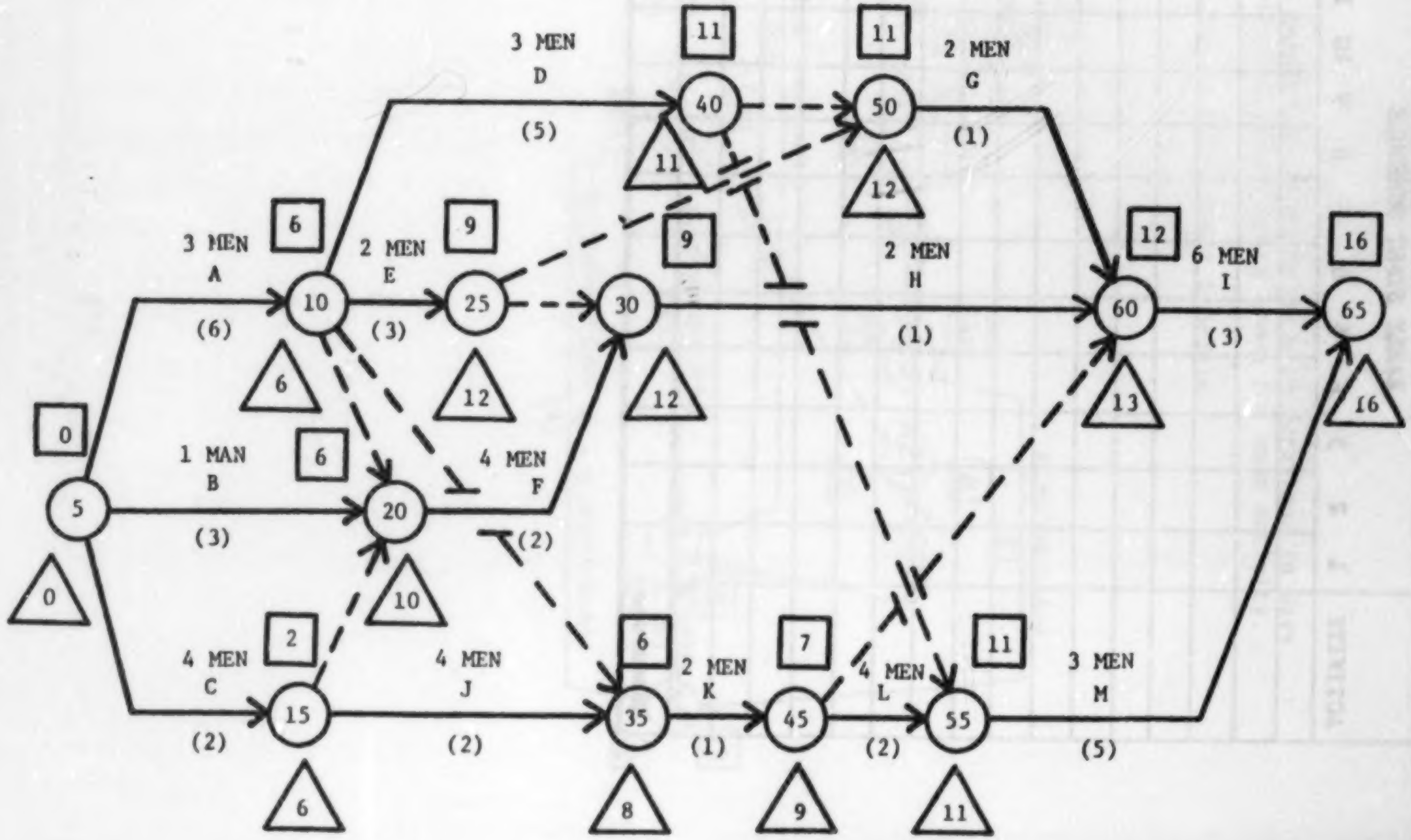
Requirement: Prepare an Early Start Schedule.


1
2 CARP.
(1)
5
4
6 CARP.
(3)
10
3
4
5 CARP.
(3)
20
6
7
25
6
7
1 ELECTRICIAN
(2)
2 CARP.
(1)
2 ELECTRICIANS
(8)
0
1
0
4 CARP.
(2)
15
2
5
2 CARPENTERS
(3)
30
8
8
6 CARP.
(5)
35
13
13
3 CARPENTERS & 1 ELECTRICIAN
(4)

	EARLY START SCHEDULE												
ACTIVITY	1	2	3	4	5	6	7	8	9	10	11	12	13
Resources													

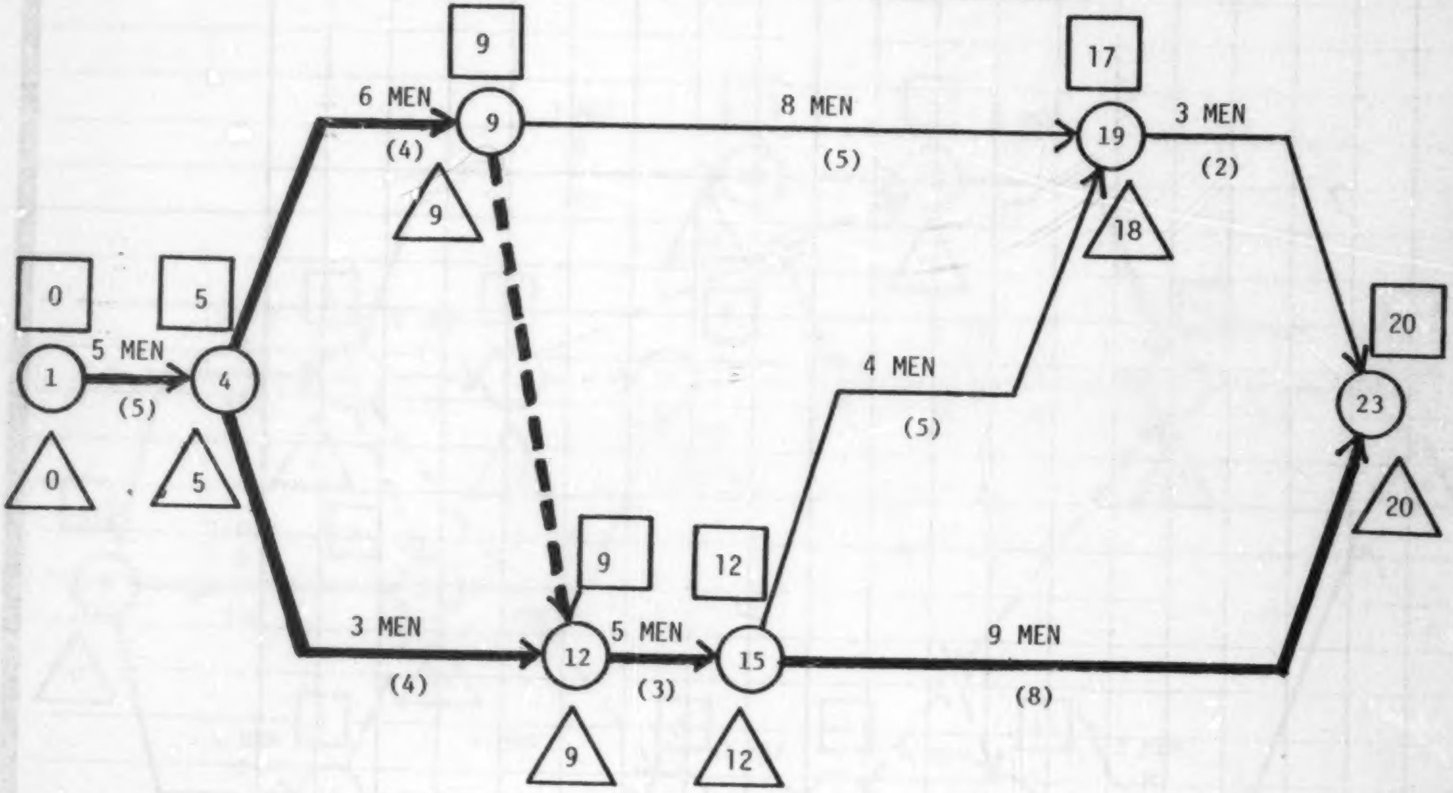
STUDENT PRACTICAL EXERCISE II

USING THE DIAGRAM BELOW CONSTRUCT A COMPLETE EARLY START SCHEDULE ON THE BLANK FORM PROVIDED.


0
5
0
3 MEN
A
(6)
6
10
6
1 MAN
B
(3)
6
20
10
4 MEN
C
(2)
2
15
6
3 MEN
D
(5)
11
40
11
2 MEN
E
(3)
9
25
12
4 MEN
F
(2)
9
30
12
11
50
12
2 MEN
G
(1)
2 MEN
H
(1)
12
60
13
6 MEN
I
(3)
16
65
16
4 MEN
J
(2)
6
35
8
2 MEN
K
(1)
7
45
9
4 MEN
L
(2)
11
55
11
3 MEN
M
(5)

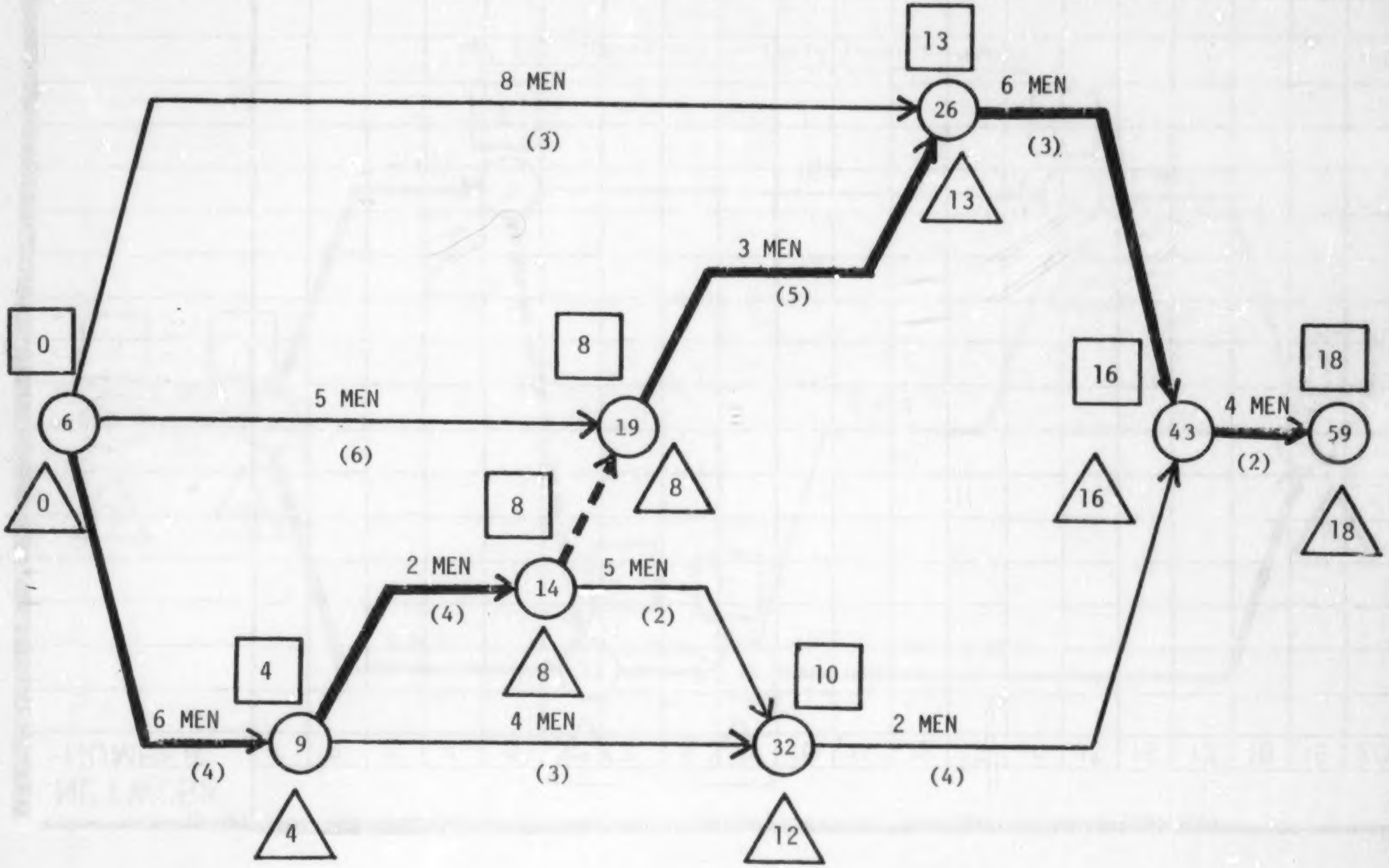
NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

PE, III. Construct an Early Start Schedule.


0
5
9
17
20
1
4
9
12
15
19
23
5 MEN
(5)
6 MEN
(4)
3 MEN
(4)
8 MEN
(5)
5 MEN
(3)
4 MEN
(5)
9 MEN
(8)
3 MEN
(2)
0
5
9
9
12
18
20
9
12

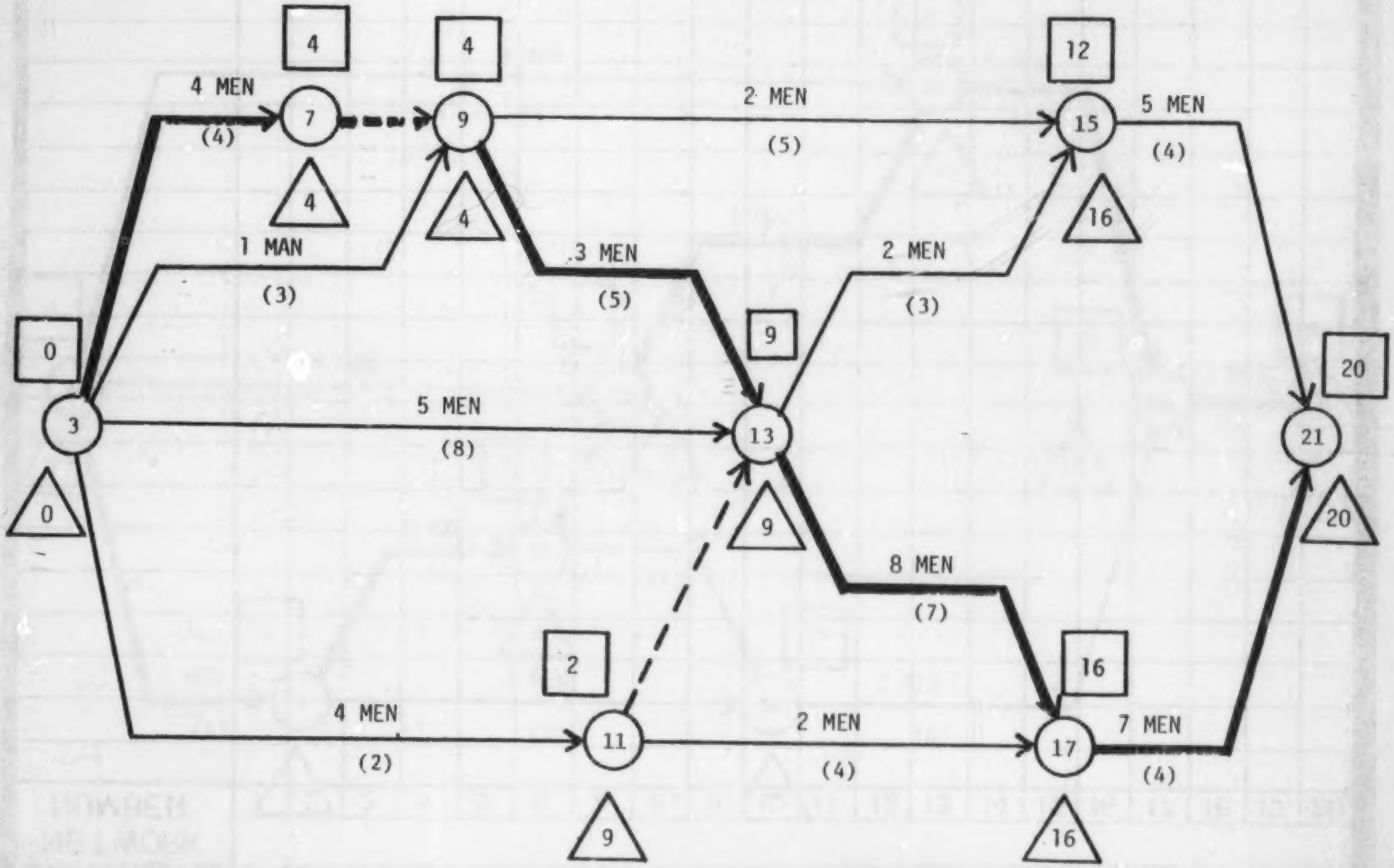
NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

PE, IV. Construct an Early Start Schedule.


0
6
0
8 MEN
(3)
13
26
13
6 MEN
(3)
5 MEN
(6)
8
19
8
3 MEN
(5)
16
43
16
4 MEN
(2)
18
59
18
6 MEN
(4)
4
9
4
2 MEN
(4)
8
14
8
5 MEN
(2)
4 MEN
(3)
10
32
12
2 MEN
(4)

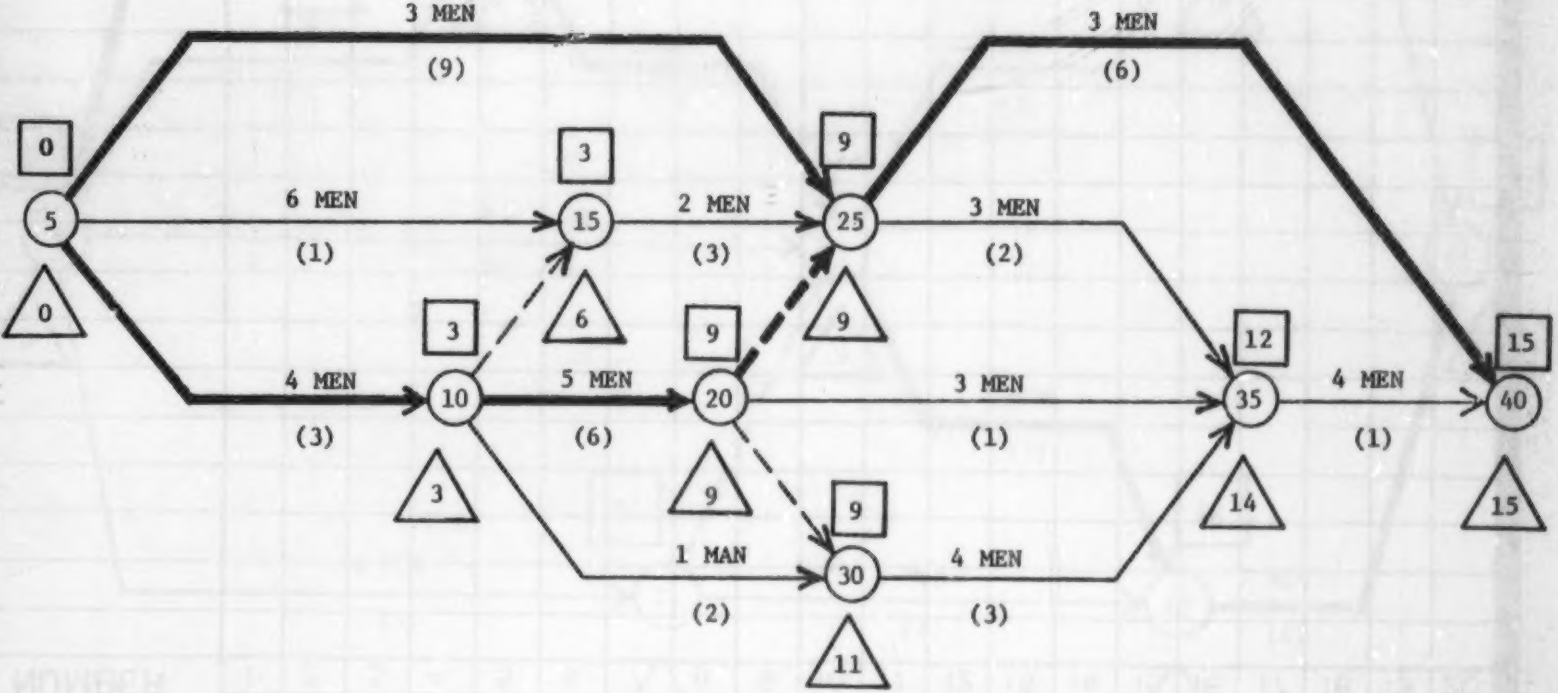
NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

PE, V. Construct an Early Start Schedule.


0
3
0
4 MEN
(4)
4
7
4
1 MAN
(3)
4
9
4
3 MEN
(5)
2 MEN
(5)
5 MEN
(8)
9
13
9
4 MEN
(2)
2
11
9
12
15
16
2 MEN
(3)
8 MEN
(7)
2 MEN
(4)
16
17
16
5 MEN
(4)
7 MEN
(4)
20
21
20

NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

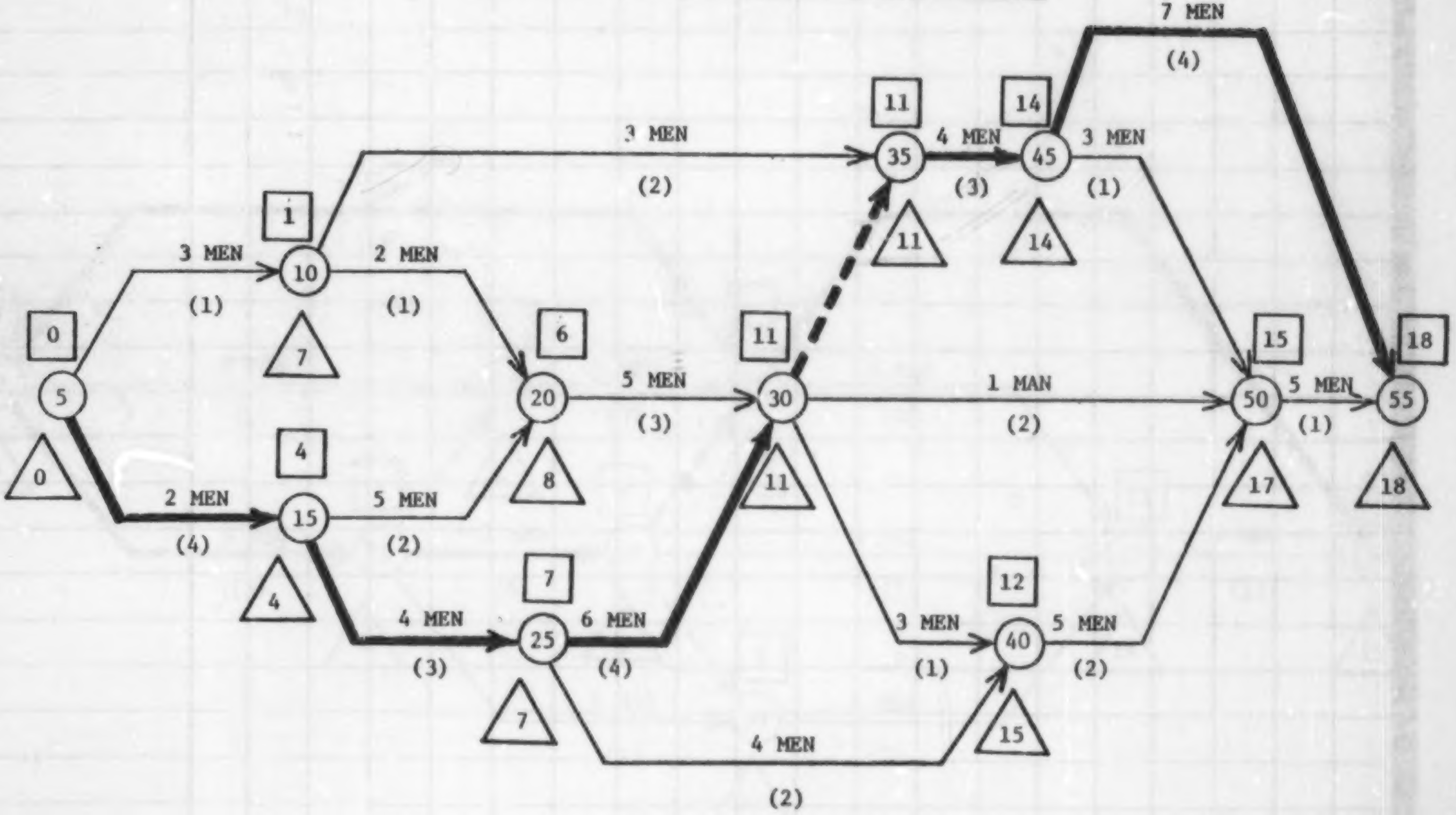
PE, VI. Construct an Early Start Schedule.



0
5
0
3 MEN
(9)
6 MEN
(1)
4 MEN
(3)
3
15
6
3
10
3
2 MEN
(3)
5 MEN
(6)
1 MAN
(2)
9
20
9
9
25
9
9
30
11
3 MEN
(6)
3 MEN
(2)
3 MEN
(1)
4 MEN
(3)
12
35
14
4 MEN
(1)
15
40
15

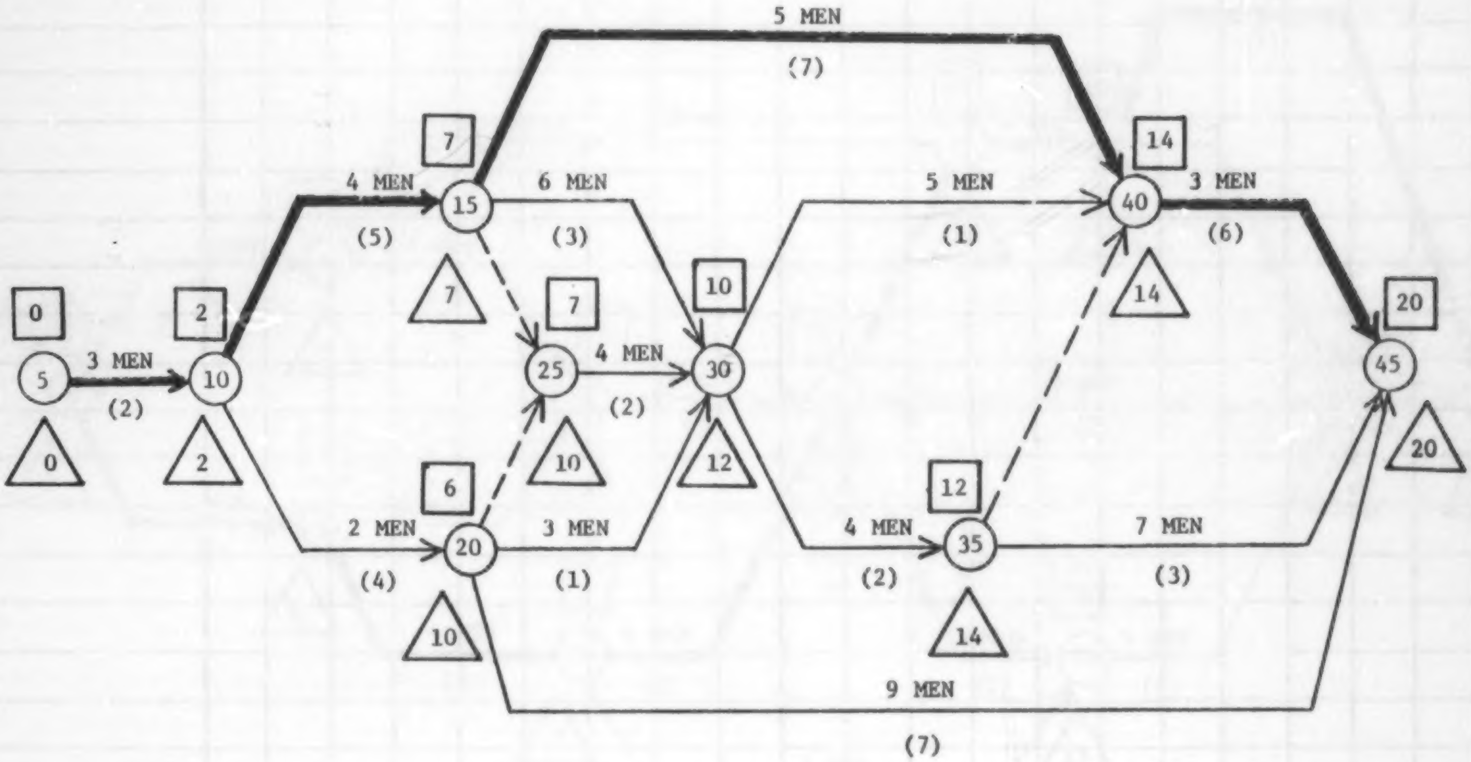
NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

PE VII. Construct an Early Start Schedule


7 MEN
(4)
11
14
3 MEN
(2)
35
4 MEN
(3)
45
3 MEN
(1)
1
11
14
3 MEN
(1)
10
2 MEN
(1)
7
0
6
11
15
18
5
20
5 MEN
(3)
30
1 MAN
(2)
50
5 MEN
(1)
55
0
4
8
11
17
18
2 MEN
(4)
15
5 MEN
(2)
4
7
12
4 MEN
(3)
25
6 MEN
(4)
3 MEN
(1)
40
5 MEN
(2)
7
15
4 MEN
(2)

NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

PE VIII. Construct an Early Start Schedule.



5
10
15
20
25
30
35
40
45
0
2
7
6
7
10
12
14
20
0
2
7
10
10
12
14
14
20
3 MEN
(2)
4 MEN
(5)
2 MEN
(4)
5 MEN
(7)
6 MEN
(3)
4 MEN
(2)
3 MEN
(1)
5 MEN
(1)
4 MEN
(2)
3 MEN
(6)
7 MEN
(3)
9 MEN
(7)

NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

SOLUTION TO SCHEDULING PE (PAGE 170)

TWO CULVERT PROBLEM

NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
5-10 (15)	2	2	X	X												
5-15	4	4	4	4	4	4										
5-20	4	4	4	4	4	4										
10-20			2	2												
15-25							6									
20-30							6									
25-35								10	10	10	10	10	10			
30-35								10	10	10	10	10	10			
TOTAL	10	10	10	10	8	8	12	20	20	20	20	20	20			

A SOLUTION FOR PRACTICAL EXERCISE I

	EARLY START SCHEDULE												
ACTIVITY	1	2	3	4	5	6	7	8	9	10	11	12	13
1-5 (10)	[2c			X]									
1-10	[6c	6c	6c	X]									
1-15 (25)	[4c	4c	X	X	X]								
1-30	[2E	2E	2E	2E	2E	2E	2E	2E]					
10-20(25)				[5c	5c	5c	X]						
15-30			[2c	2c	2c			]					
15-35			[3c/1E	3c/1E	3c/1E	3c/1E							]
20-35							[1E	1E					]
25-30							[2c	]					
30-35									[6c	6c	6c	6c	6c]
Resources	12c/2E	10c/2E	11c/3E	10c/3E	10c/3E	8c/3E	2c/3E	0/3E	6c/0	6c/0	6c/0	6c/0	6c/0

SOLUTION TO STUDENT PRACTICAL EXERCISE II

NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
5-10(20)(35)	3	3	3	3	3	3											
5-15 (20)	4	4	X	X	X	X											
5-20	1	1	1				X	X	X	X							
10-25(30)(50)							2	2	2	X	X	X					
10-40(50)(55)							3	3	3	3	3						
15-35			4	4			X	X									
20-30							4	4		X	X	X					
30-60										2			X				
35-45(60)							2	X	X								
45-55								4	4								
50-60												2	X				
55-65												3	3	3	3	3	
60-65													6	6	6		
TOTAL																	
MEN	8	8	8	7	3	3	11	13	9	5	3	5	9	9	9	3	

NETWORK NUMBER	SOLUTION SCHEDULING PROBLEM III,																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1 - 4	5	5	5	5	5															
4 - 9 (12)						6	6	6	6											
4 - 12						3	3	3	3											
9 - 19										8	8	8	8	8				X		
12 - 15										5	5	5								
15 - 19													4	4	4	4	4	X		
15 - 23													9	9	9	9	9	9	9	9
19 - 23																		3	3	
TOTAL	5	5	5	5	5	9	9	9	9	13	13	13	21	21	13	13	13	12	12	9

NETWORK NUMBER	SOLUTION SCHEDULING PROBLEM																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6 - 9	6	6	6	6																
6 - 19	5	5	5	5	5	5														
6 - 26	8	8	8																	
9 - 14 (19)					2	2	2	2												
9 - 32					4	4	4				X	X								
14 - 32									5	5	X	X								
19 - 26									3	3	3	3	3							
26 - 43														6	6	6				
32 - 43											2	2	2	2						
43 - 59																	4	4		
TOTAL	19	19	19	11	11	11	6	2	8	8	5	5	5	8	6	6	4	4		

SOLUTION SCHEDULING PROBLEM V,

NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
3 - 7 (9)	4	4	4	4																
3 - 9	1	1	1																	
3 - 11 (13)	4	4	X	X	X	X	X	X	X											
3 - 13	5	5	5	5	5	5	5	5												
9 - 13					3	3	3	3	3											
9 - 15					2	2	2	2	2				X	X	X	X				
11 - 17			2	2	2	2														
13 - 15										2	2	2	X	X	X	X				
13 - 17										8	8	8	8	8	8	8				
15 - 21													5	5	5	5				
17 - 21																	7	7	7	7
TOTAL	14	14	12	11	12	12	10	10	5	10	10	10	13	13	13	13	7	7	7	7

pages tightly bound

NETWORK NUMBER	SOLUTION SCHEDULING PROBLEM VI,																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5-10(15)	4	4	4																	
5-15	6			X	X	X														
5-25	3	3	3	3	3	3	3	3	3											
10-20(25) (30)				5	5	5	5	5	5											
10-30				1	1					X	X									
15-25				2	2	2														
20-35										3			X	X						
25-35										3	3		X	X						
25-40										3	3	3	3	3	3					
30-35										4	4	4	X	X						
35-40													4							
TOTAL	13	7	7	11	11	10	8	8	8	13	10	7	7	3	3					

SOLUTION SCHEDULING PROBLEM VII

NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5-10	3	X	X	X	X	X	X													
5-15	2	2	2	2																
10-20		2					X	X												
10-35		3	3																	
15-20					5	5	X	X												
15-25					4	4	4													
20-30(35)							5	5	5											
25-30(35)								6	6	6	6									
25-40								4	4				X	X	X					
30-40												3	X	X	X					
30-50												1	1			X	X			
35-45												4	4	4						
40-50													5	5		X	X			
45-50															3	X	X			
45-55															7	7	7	7		
50-55																5				
TOTAL	5	7	5	2	9	9	9	15	15	6	6	8	10	9	10	12	7	7		

SOLUTION SCHEDULING PROBLEM VIII

NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5-10	3	3																		
10-15(25)			4	4	4	4	4													
10-20(25)			2	2	2	2	X	X	X	X										
15-30								6	6	6	X	X								
15-40								5	5	5	5	5	5	5						
20-30							3				X	X								
20-45							9	9	9	9	9	9	9							
25-30								4	4		X	X								
30-35(40)											4	4	X	X						
30-40											5									
35-45													7	7	7					
40-45															3	3	3	3	3	3
TOTAL	3	3	6	6	6	6	16	24	24	20	23	18	21	12	10	3	3	3	3	3

TABULATION SHEET

TABULATION SHEET

After the time analysis is complete a TABULATION SHEET is constructed as shown below. The tab sheet is a consolidation of all the information contained on the logic diagram. Because of its compact tabular form front line supervisors can quickly see when activities may start and must end in order to achieve the project completion time. The tab sheet, however, will in no way replace the logic diagram and schedule in showing the effects delays will have on the project as a whole.

TABULATION SHEET

Activity	Duration	Early Start	Early Finish	Late Start	Late Finish	Total Float
	○⟶○ ( )	□ ○⟶○	ES+DUR	LF-DUR	○⟶○ △	LF-EF or LS-ES

List all the activities in numerical order from lowest to highest. This aids in locating an activity within the tab sheet while the activity numbers themselves describe the project's logical sequence.

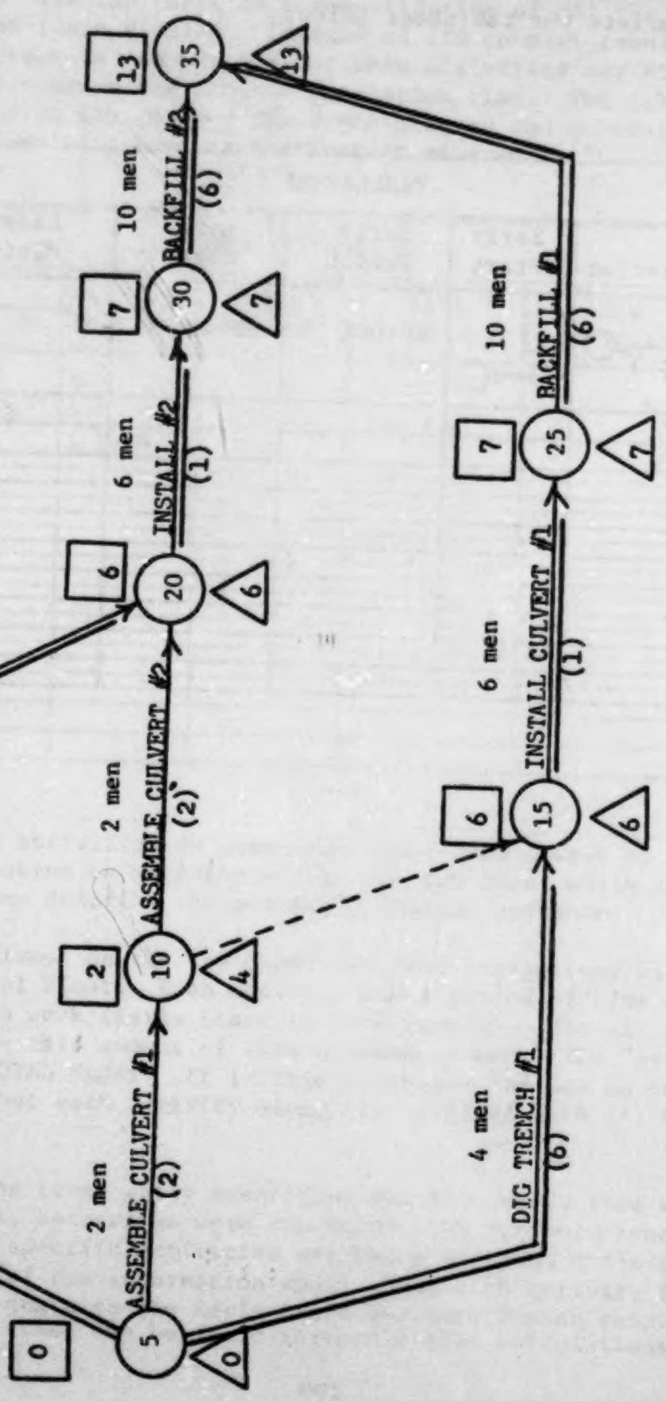
The other columns on the tab sheet are self-explanatory with the exception of Total Float. Each activity has a period of time in which to accomplish the work (Early Start to Late Finish). Not all the activities will require this amount of time allowed by CPM. The "extra" time, if any, is called TOTAL FLOAT. It is time a manager can use to control the project. Note that each activity along the critical path (*) will have zero float.

Previously the terms early event time and late event time were used in the time analysis, because we were concerned with the occurrence of an event. Now that specific activities are being analyzed different terms are used. Only part of the information known about each activity is found in the EET and LET and equate to the Early Start and Late Finish respectively. The remainder of the times can be found through simple calculations.

TABULATION SHEET PE 1

Using the results from the time analysis for the Two Culvert problem complete the tab sheet below:

TABULATION SHEET						
Activity	Duration	Early Start	Early Finish	Late Start	Late Finish	Total Float
	○→○ ( )	□ ○→○	ES+DUR	LF-DUR	○→○ △	LF-EF LS-ES

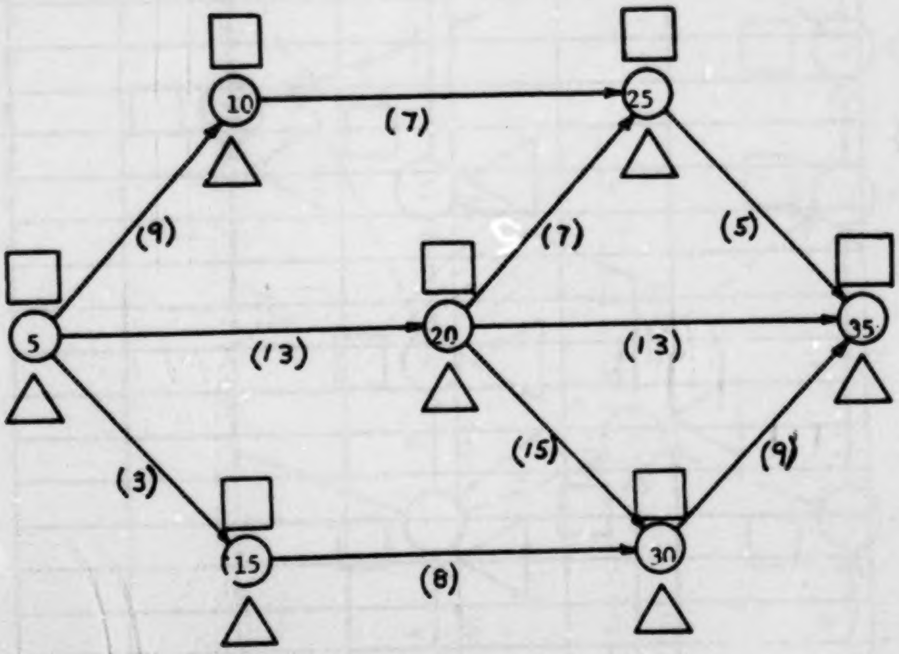
0
5
0
ASSEMBLE CULVERT #1
(2)
2 men
2
10
4
ASSEMBLE CULVERT #2
(2)
2 men
6
20
6
INSTALL #2
(1)
6 men
7
30
7
BACKFILL #2
(6)
10 men
13
35
13
DIG TRENCH #2
(6)
4 men
DIG TRENCH #1
(6)
4 men
6
15
6
INSTALL CULVERT #1
(1)
6 men
7
25
7
BACKFILL #1
(6)
10 men
13

STUDENT PRACTICAL EXERCISE II

Requirement A: Calculate the Earliest Event Time for each event and place answer in square provided over appropriate number.

Requirement B: Calculate the latest event times and insert answers in triangles under appropriate numbers.

Requirement C: Complete the Tabulation Sheet for the network shown below.

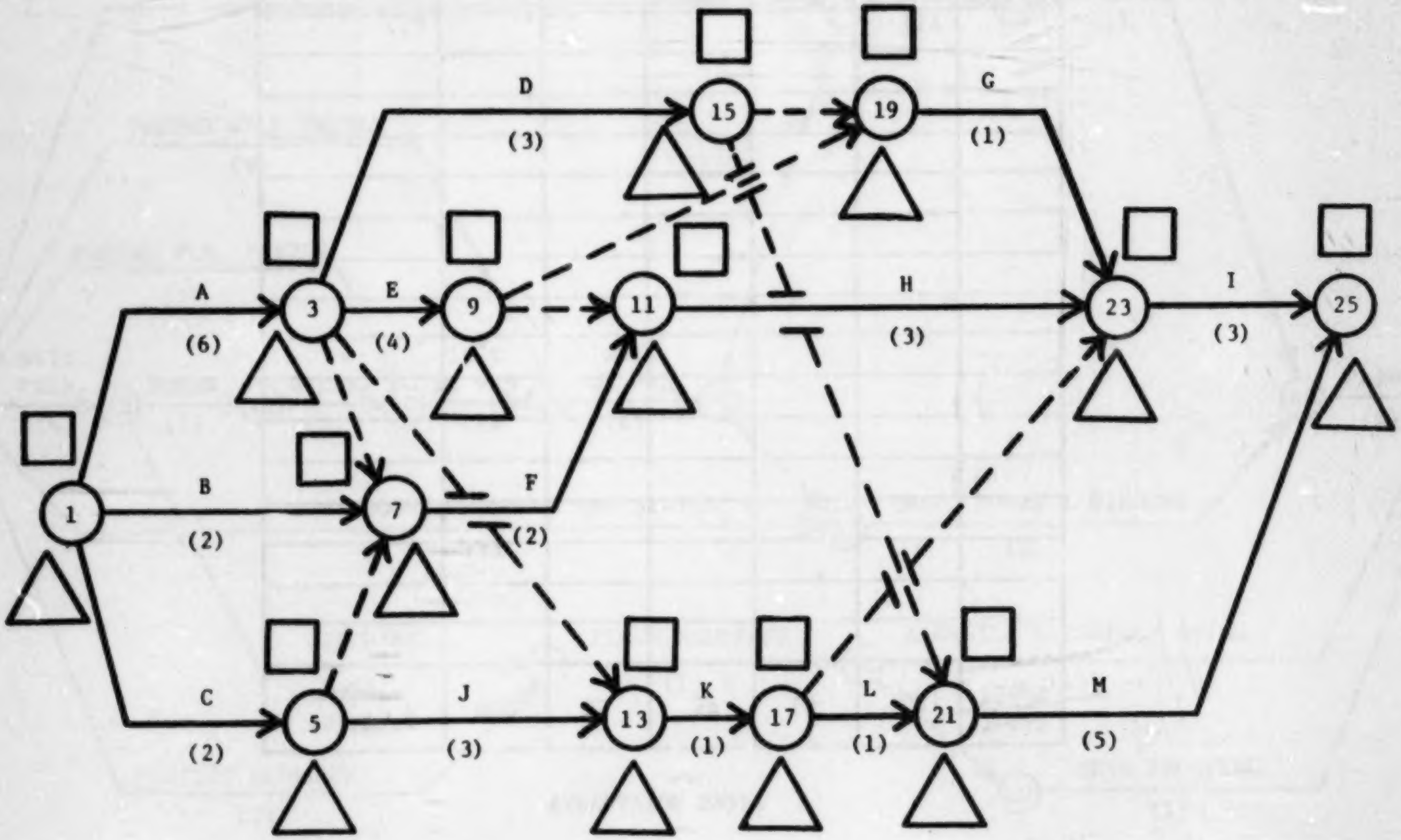


TABULATION SHEET

Activity Numbers	DUR	ES	EF	LS	LF	Total Float

STUDENT PRACTICAL EXERCISE III

USING THE DIAGRAM BELOW : A) CALCULATE THE EET's AND LET's
B) IDENTIFY THE CRITICAL PATH(S)
C) COMPLETE THE TAB SHEET ON THE OPPOSITE PAGE


1
3
5
7
9
11
13
15
17
19
21
23
25
A
(6)
B
(2)
C
(2)
D
(3)
E
(4)
F
(2)
G
(1)
H
(3)
I
(3)
J
(3)
K
(1)
L
(1)
M
(5)

TABULATION SHEET

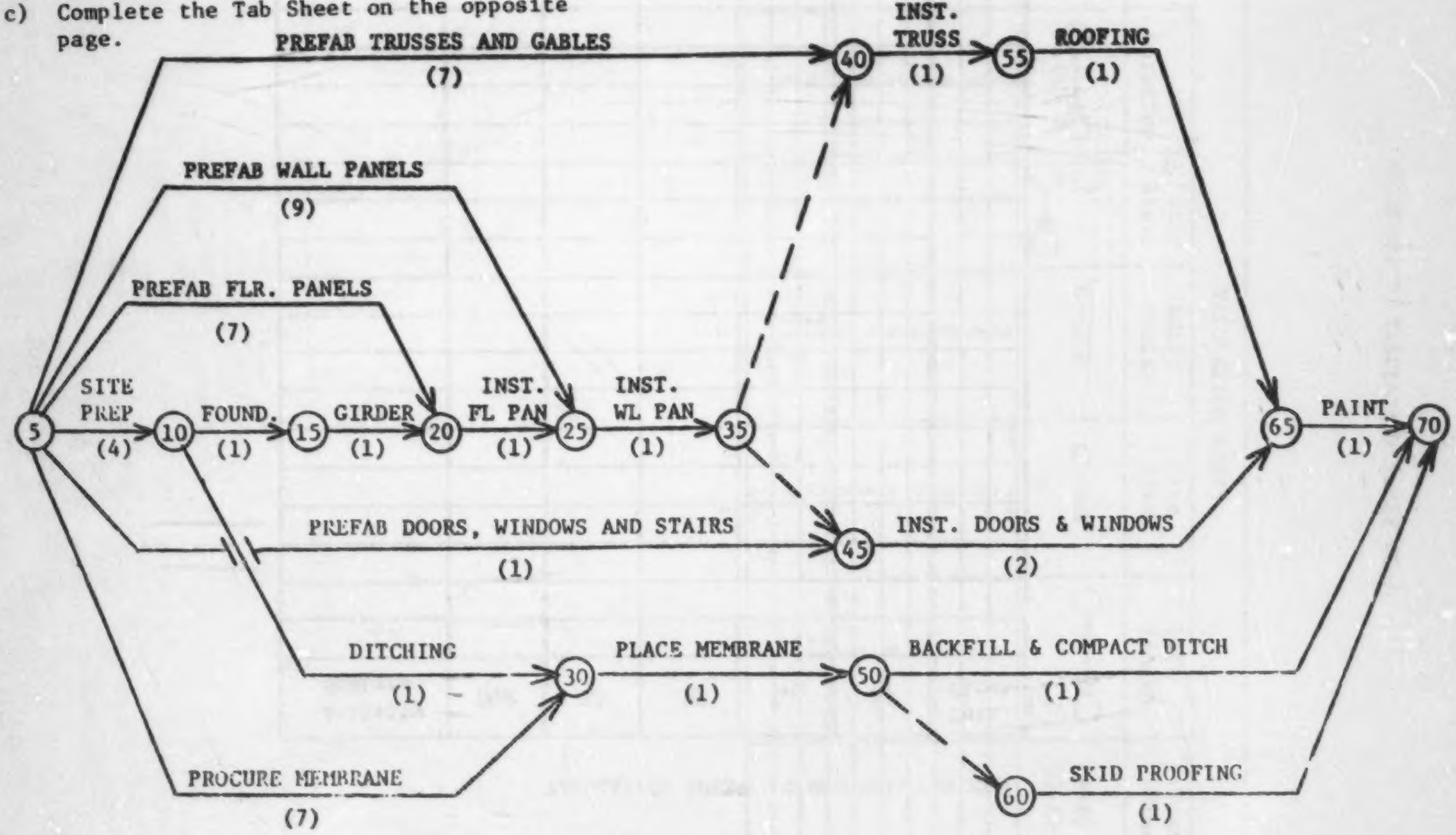
Activity Numbers	DUR	ES	EF	LS	LF	Total Float

STUDENT PRACTICAL EXERCISE IV

Using the diagram below:

a) Calculate the EET's and LET's.
b) Identify the Critical Path(s).
c) Complete the Tab Sheet on the opposite page.

TRAINING BUILDING


5
SITE PREP
(4)
10
FOUND.
(1)
15
GIRDER
(1)
20
INST. FL PAN
(1)
25
INST. WL PAN
(1)
35
PREFAB TRUSSES AND GABLES
(7)
40
INST. TRUSS
(1)
55
ROOFING
(1)
65
PAINT
(1)
70
PREFAB WALL PANELS
(9)
PREFAB FLR. PANELS
(7)
PREFAB DOORS, WINDOWS AND STAIRS
(1)
45
INST. DOORS & WINDOWS
(2)
DITCHING
(1)
30
PLACE MEMBRANE
(1)
50
BACKFILL & COMPACT DITCH
(1)
PROCURE MEMBRANE
(7)
60
SKID PROOFING
(1)

TABULATION SHEET

Activity Numbers	DUR	ES	EF	LS	LF	Total Float

SOLUTION TO TABULATION SHEET PE 1

TABULATION SHEET						
Activity	Duration	Early Start	Early Finish	Late Start	Late Finish	Total Float
	○→○ ( )	□ ○→○	ES+DUR	LF-DUR	○→○ △	LF-EF LS-ES
5-10	2	0	2	2	4	2
5-15	6	0	6	0	6	0
5-20	6	0	6	0	6	0
10-15	0	2	2	6	6	4
10-20	2	2	4	4	6	2
15-25	1	6	7	6	7	0
20-30	1	6	7	6	7	0
25-35	6	7	13	7	13	0
30-35	6	7	13	7	13	0

A SOLUTION TO STUDENT PRACTICAL EXERCISE II

TABULATION

TASKS	DURATION	E.S.	E.F.	L.S.	L.F.	FLOAT	
5-10	9	0	9	16	25	16	
5-15	3	0	3	17	20	17	
5-20	13	0	13	0	13	0	***
10-25	7	9	16	25	32	16	
15-30	8	3	11	20	28	17	
20-25	7	13	20	25	32	12	
20-30	15	13	28	13	28	0	***
20-35	13	13	26	24	37	11	
25-35	5	20	25	32	37	12	
30-35	9	28	37	28	37	0	***

SOLUTION TO STUDENT PRACTICAL EXERCISE III

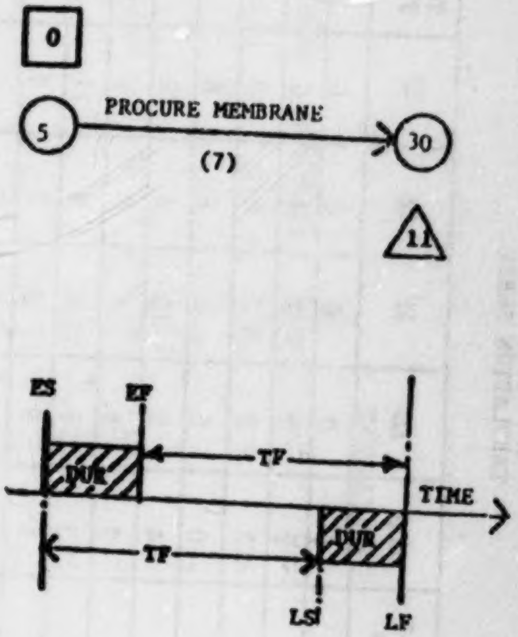
TABULATION SHEET

Activity Numbers	DUR	ES	EF	LS	LF	Total Float	
1 - 3	6	0	6	0	6	0	*
1 - 5	2	0	2	4	6	4	
1 - 7	2	0	2	6	8	6	
3 - 7	0	6	6	8	8	2	
3 - 9	4	6	10	6	10	0	*
3 - 13	0	6	6	9	9	3	
3 - 15	3	6	9	8	11	2	
5 - 7	0	2	2	8	8	6	
5 - 13	3	2	5	6	9	4	
7 - 11	2	6	8	8	10	2	
9 - 11	0	10	10	10	10	0	*
9 - 19	0	10	10	12	12	2	
11 - 23	3	10	13	10	13	0	*
13 - 17	1	6	7	9	10	3	
15 - 19	0	9	9	12	12	3	
15 - 21	0	9	9	11	11	2	
17 - 21	1	7	8	10	11	3	
17 - 23	0	7	7	13	13	6	
19 - 23	1	10	11	12	13	2	
21 - 25	5	9	14	11	16	2	
23 - 25	3	13	16	13	16	0	*

SOLUTION TO STUDENT PRACTICAL EXERCISE IV

TABULATION

ACT	DUR	ES	EF	LS	LF	TOT FLT
5 - 10	4	0	4	2	6	2
5 - 20	7	0	7	1	8	1
5 - 25	9	0	9	0	9	0 *
5 - 30	7	0	7	4	11	4
5 - 40	7	0	7	3	10	3
5 - 45	1	0	1	9	10	9
10 - 15	1	4	5	6	7	2
10 - 30	1	4	5	10	11	6
15 - 20	1	5	6	7	8	2
20 - 25	1	7	8	8	9	1
25 - 35	1	9	10	9	10	0 *
30 - 50	1	7	8	11	12	4
35 - 40	0	10	10	10	10	0 *
35 - 45	0	10	10	10	10	0 *
40 - 55	1	10	11	10	11	0 *
45 - 65	2	10	12	10	12	0 *
50 - 60	0	8	8	12	12	4
50 - 70	1	8	9	12	13	4
55 - 65	1	11	12	11	12	0 *
60 - 70	1	8	9	12	13	4
65 - 70	1	12	13	12	13	0 *


0
5
PROCURE MEMBRANE
(7)
30
11
ES
EF
DUR
TF
TIME
TF
DUR
LS
LF

SELF-EVALUATION QUESTIONS, SCHEDULING I

1. Why do we construct the Early Start Schedule?

2. What are the two types of float time?

3. How do you identify interfering float time periods?

4. What do the brackets of the time frame represent?

5. If you have a delay in the project, why do you delay the activities with free float first?

6. What happens if a non-critical activity is delayed outside its time frame?

SELF-EVALUATION QUESTION SCHEDULING II

1. **Discuss the schedule as a management information tool.**

2. **How can you use the information found in the schedule for reports?**

3. **What training uses does the schedule have?**

SOLUTIONS TO SELF-EVALUATION QUESTIONS, SCHEDULING I

1. We construct the Early Start Schedule because it gives us the greatest flexibility to deal with changes and delays because all the float time follows the scheduled resource utilization.

2. Free Float and Interfering Float.

3. Consider a specific activity. If the activity has float time available, first locate all activities which cannot start until this activity has finished. These "dependent activities" will either begin at the event node at the head of the activity, or they will start at the heads of dummy arrows coming from this activity. Next, identify the earliest time column in which a "dependent activity" is scheduled to begin. If you can delay the first activity into this identified time column, you have delayed into interfering float. Once this interfering float column has been identified, all the rest of the activity's float time to the right of this column is also interfering float.

4. The earliest possible starting time and the latest possible finish time that will not delay the project.

5. The move will cause the least total effect on the project.

6. The project will be delayed by the number of time periods used to the right of the end bracket.

PROJECT CONTROL

LESSON: Project Control

OBJECTIVE: The student, using all previous lessons; and given a completed schedule and logic diagram, will be able to adjust the schedule to complete the project on time.

REFERENCES: TM 5-333, para 4-1 thru 4-11.

STUDENT NOTES

PROJECT CONTROL

Control, a vital element in project management, is a continuing process which adjusts the operations to the situation in order to accomplish the desired objective. The best plan and schedule known to man will not get the work done unless other management tools are implemented. No plan was ever executed exactly as the planner intended. A good project manager is able to react to changing situations quickly and effectively in order to guide the project to a successful conclusion.

1. Control Information.

The manager must have a method of keeping track of what is happening on the project site as well as other factors which may influence the progress of the project. He requires several sources of information for keeping track of his project's progress as well as controls which he can manipulate to affect changing situations.

a. Progress reports. Properly designed progress reports can give the manager a good deal of information about a project in a short period of time; however, the manager will be seeing the situation through another person's eyes

(1) Daily update reports are normally oral.

(2) Weekly reports to battalion and higher may vary in nature, depending on the kind of project, and do not always fill the needs of the company level manager.

b. Inspections. Inspections give the manager first-hand knowledge of the situation and provide immediate feedback. However, inspections are time-consuming and they should be planned to accomplish a definite purpose. Some balance between inspections and progress reports must be struck to enable the manager to use his time most efficiently.

c. Constraints. Invariably, events occur which hinder efficient progress of a project. A piece of equipment breaks down, manpower shortages occur through sickness, leave, extra duties, unfilled unit vacancies. All of these and other constraints which may occur will affect the length of the project. Orders to expedite the project also will force the manager to develop and implement a new plan of action.

d. Decisions. Through reports, inspections, and identification of constraints, the manager must make decisions which alter the project plan to bring it back on schedule and guide it to a successful completion. The following resources are available which the manager can manipulate to achieve his desired objectives.

(1) Money/materials. These resources equate as materials cost money.

(2) Men.

(3) Equipment.

(4) Time.

[illegible]. Project Control Procedures.

A detailed CPM schedule is a project control device which helps the manager identify activities on which he should focus his attention. There is very little guesswork involved in the preparation or the reading of a CPM schedule progress report. Activities are either completed, in progress, or not started. Once the manager determines that an activity is headed for trouble (if not already in trouble!), he should develop a course of corrective action to insure that the overall project is not jeopardized. Using his CPM network and schedule, the manager should proceed in the following manner:

a. Delay the activities. What effect does the change in conditions have? Which activity is directly affected? If it is delayed, which other activities will also be delayed?

b. Re-sum the resources. If the activities are delayed, what will happen to the resource allocations? Are there now resource conflicts?

c. Update the network. Are there changes in the critical path? What happens to the overall project duration? What other changes occur in the network? Is float changed in non-critical activities? Do resource dummy activities have to be added?

d. Update the schedule. Changes that are found in updating the network must now be added to the schedule.

3. Control Methods.

The manager of the project should use whatever knowledge, expertise, and ideas that are available as he develops a course of action. Ingenuity is a valuable trait at this point in time. The proficient manager will usually choose some appropriate combination of several possible solutions. He should give consideration to the following methods:

a. Analyze resource utilization. Poor use of men and equipment is not infrequent, particularly in units with less experienced troops. Re-analyze each activity. Is the proper combination of men and equipment being utilized? What improvements in the layout of the construction site could be made? Would an alternate construction method be better for the task at hand? A proper adjustment in any of these areas resulting in an improvement in productivity could shorten the overall activity duration. Utilization of any idle resources should also be considered.

b. Re-locate men and equipment. Equipment breakdowns, lack of proper equipment, manpower shortages, and lack of key personnel with the required expertise can slow a project down in short order. What can be done to alleviate these problems? The range of solutions may be limited, but sometimes a simple re-alignment in personnel or equipment can produce dramatic results.

c. Re-estimate activity durations. As the project progresses, it will become evident that some of the original estimates of activity durations are not completely accurate. Some activities take longer than planned; others go more smoothly than anyone could have imagined. Frequent re-assessments of activity durations and resource requirements should be made to give the manager sufficient information to re-balance the resource allocations for various activities. On smoothly-run projects, operations flow from one to another, and abrupt resource changes from day to day are uncommon. The good manager will plan ahead to insure that this continuity is maintained whenever possible.

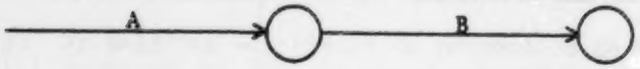
Network Number	1	2	3	4	5	6	7	8	9	10	11	
5-10	7m	7m	7m	7m	X	X						

Std Effort	Efficiency	Troop Effort	Crew Size	Duration	Remarks
28MD	100%	28MD	7 men	4 days	Original Estimate
28MD	100%	28MD	5 men	5 or 6 days	New crew size
28MD	70%	40MD	5 men	8 days	Different crew size and efficiency

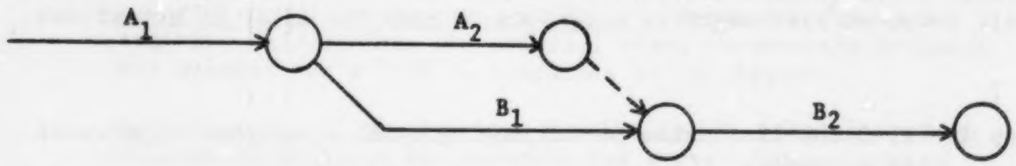
d. Redefine the CPM Logic. The manager should review all the activities on the critical path. Sometimes, preferential logic creeps into the network. This is when a preferred sequence is not actually a logic constraint. There are two ways the logic can be redefined.

(1) Move the activities within the network. This is a technique that should be used when it is found that two sequential activities could be done concurrently.

(2) Split an activity into two or more separate parts. In many cases it is convenient to estimate all of the effort involved in a task, but during work only a portion needs to be done before starting work on a succeeding activity.



to



e. Expedite the project. When a project starts falling behind schedule, or when project completion dates are shortened, sometimes the only solution is to place more resources on the critical activities in order to "catch up." This can be accomplished by going to an extended workday, double-shifting, working on weekends, and/or adding more men and equipment. Normally, a moderately extended workday is the most economical and productive approach; however, certain considerations may make this infeasible.

REMEMBER THAT YOU MUST REDUCE THE ACTIVITIES

ON THE CRITICAL PATH TO REDUCE THE PROJECT'S

DURATION.

RESOURCE CONSTRAINTS AND SCHEDULING

INTRODUCTION

The project manager is constantly faced with the problem of limited resources. In this lesson, we want to discuss a procedure that allows the manager to resource constrain the schedule to fit his projected resource limits. This basic activity of resource balancing has caused managers innumerable problems. In many cases the manager has unknowingly changed the logic of the project and added critical paths. We must understand the effects of resource constraining the schedule so that we can continue to gain useful management information from the schedule for control of the project. This sounds easy, but in reality there is a major pitfall that must be avoided. We have to recognize that in balancing the schedule according to our resources, we may change the existing logic associations. If we fail to correct the network and schedule for these resource influenced changes, the manager will find the usefulness of the schedule severely diminished.

CONSTRAINING PROCEDURE

The following procedure is one way that we can evaluate and reflect the effects of resource constraints. To keep the example and procedure in its basic form, we will restrict ourselves to only the delay of activities.

Step 1: Find the first time period during which a resource constraint is exceeded.

Step 2:
- a. From the activities scheduled during that time frame, choose the activity with the largest float, and delay that activity one time unit.
- b. Use free float whenever possible, as this will minimize the effect on other activities.
- c. As a guide since we must realize that this step is one of trial and error, we should delay an activity with Free Float first; one with Interfering Float second; and as a last resort should we delay a Critical Activity.

Step 3: If the activity is not delayed into Free Float we must follow the delay through the schedule and then resum the resources required.

Step 4: Movement of one activity may not be enough to satisfy the resource limits, and a second activity may have to be delayed.

Step 5: Move to the next time period that the required resources exceed the resources available and repeat steps 2 thru 4 until the entire schedule has been adjusted to meet the resource constraints. Remember the following:

a. A delay that moves an activity into interfering float will cause a logic delay elsewhere in the schedule.

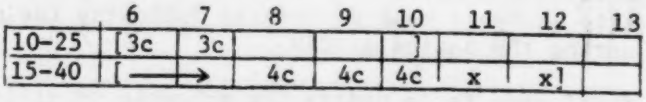
b. A delay that moves a critical activity or moves an activity outside the right bracket of the time frame increases the duration of the project.

c. A key objective in this procedure is to make as few delays as possible, and to prevent as few activities as possible from falling on the critical path. There are often several possible solutions and the manager must attempt to pick the most economical for his situation.

Step 6: By delaying activities to correspond to resource constraints, the logic of the network may be changed. A "resource dummy" (- R - R - R→) is added to the network to reflect the changes in logic caused by the lack of resources.

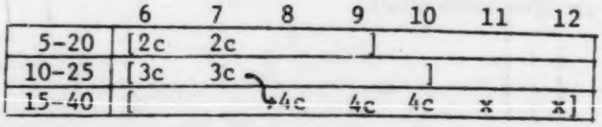
a. Identification of the cause of delay: Determine for each activity delayed from its original start whether the activity was delayed for a lack of resources or for logic.

b. Determination of the resource dummies in the schedule: Each delayed activity in the schedule has a preceding unrelated activity which uses the same resource and ends during the immediately preceeding time frame.



	6	7	8	9	10	11	12	13
10-25	[3c	3c			]			
15-40	[———	→	4c	4c	4c	x	x]	

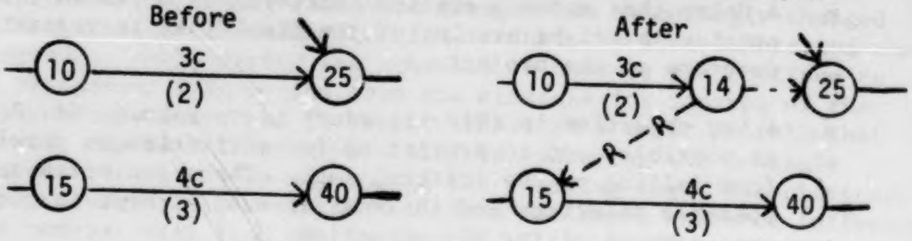
If there are two or more possible preceding activities that use the same resource, you must choose one. Having located this preceding activity, draw an arrow from the end of the preceding activity to the beginning of the delayed activity.



	6	7	8	9	10	11	12
5-20	[2c	2c		]			
10-25	[3c	3c ↷			]		
15-40	[		→4c	4c	4c	x	x]

Another point to remember is that one activity may require assets from two or more activities or one activity may provide assets to two or more activities.

c. Introduction of the resource Dummy into the network: The network must be redrawn to reflect the new resource constraints. New event nodes and logic dummies may also have to be added to accurately indicate the relationships.



The student may find that there are two helpful questions in determining the location of resource dummies, and where additional event nodes are required.

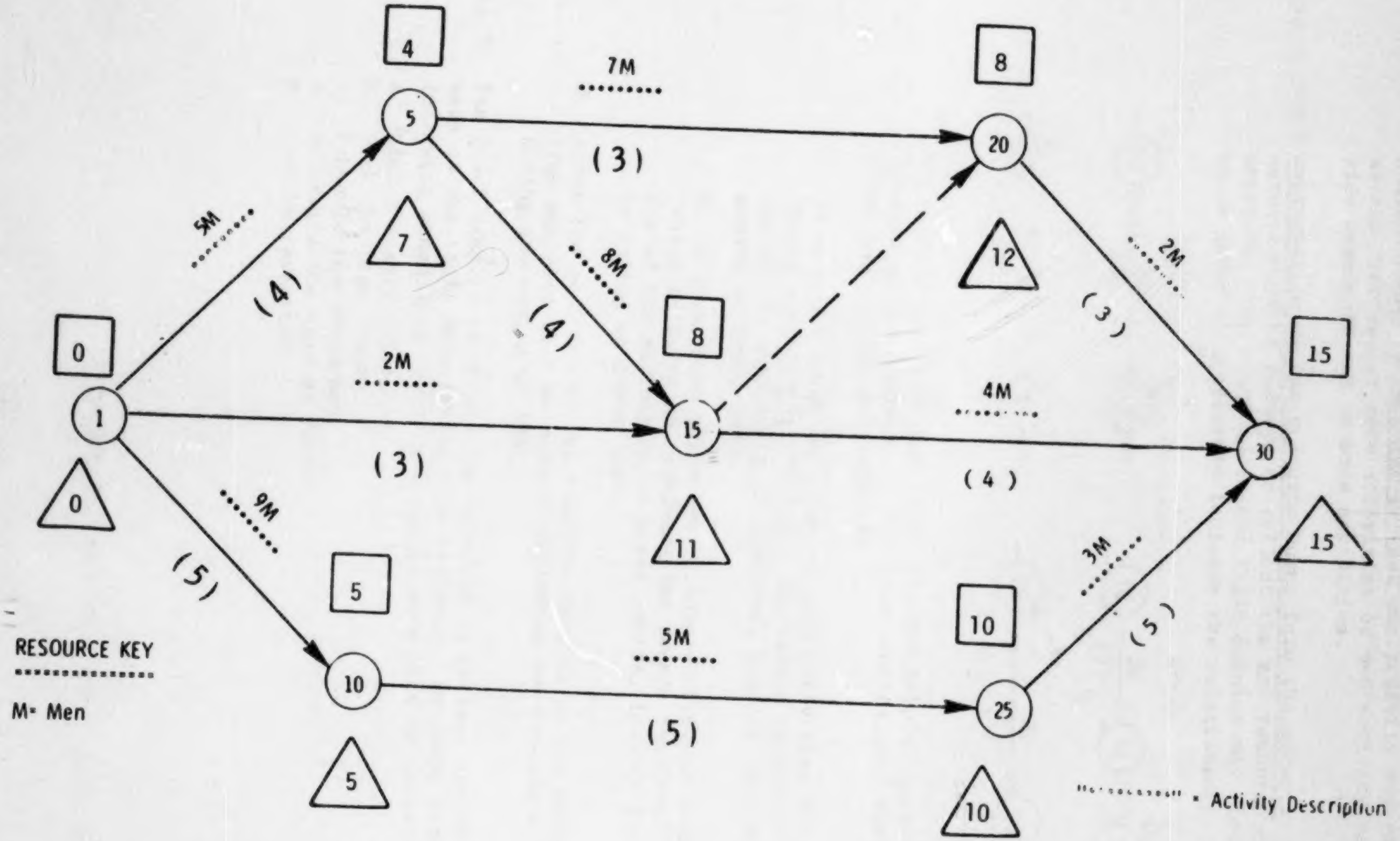
1. At an event node where two or more activities end, ask "Which activity is providing the assets required?" If only one of the activities is involved, isolate that activity by adding an event node.
2. At an event node where two or more activities begin ask "Which activity is receiving the assets required?" If only one of the activities required assets, isolate that activity by adding an event node.

d. After the addition of the resource dummies to the network, the time analysis must be updated following the procedure learned during the basics of CPM.

Step 7: The final step is to update the schedule to reflect the changes made to the logic diagram and time analysis. By going through the following scheduling steps, you can be sure that no omissions occur.

a. List the activities.
b. Mark the time frames.
c. Schedule the resources.
d. Determine the type of float.
e. Sum the resources.

STUDENT NOTES


0
1
0
4
5
7
8
15
11
8
20
12
15
30
15
5
10
5
10
25
10
5M
(4)
2M
(3)
9M
(5)
7M
(3)
8M
(4)
4M
(4)
2M
(3)
5M
(5)
3M
(5)
RESOURCE KEY
M= Men
= Activity Description

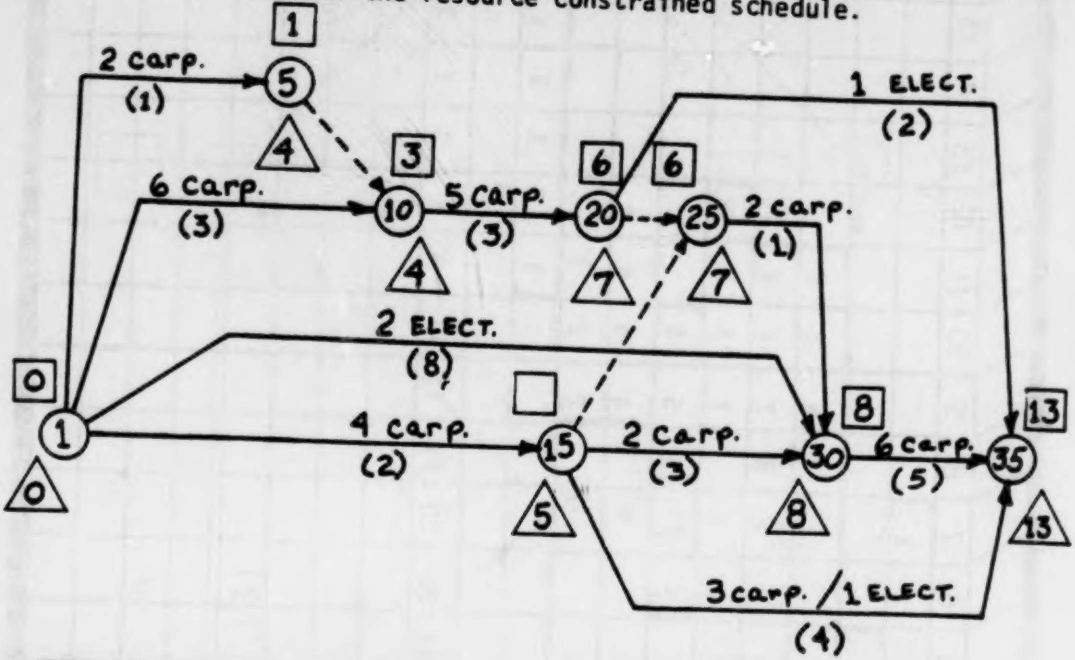
NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 - 5	5	5	5	5	X	X	X										
1 - 10	9	9	9	9	9												
1 - 15 (20)	2	2	2						X	X	X						
5 - 15 (20)					8	8	8	8	X	X	X						
5 - 20					7	7	7		X	X	X	X					
10 - 25						5	5	5	5	5							
15 - 30									4	4	4	4					
20 - 30									2	2	2						
25 - 30											3	3	3	3	3		
TOTALS	16	16	16	14	24	20	20	13	11	11	9	7	3	3	3		

PROBLEM #1

Purpose: To give the student practice in resource constraining a logic network.

Situation: Given the resource constrained schedule below with logic and resource delays.

Requirement: a. Add the resource dummies where required.
b. Redraw the resource constrained schedule.

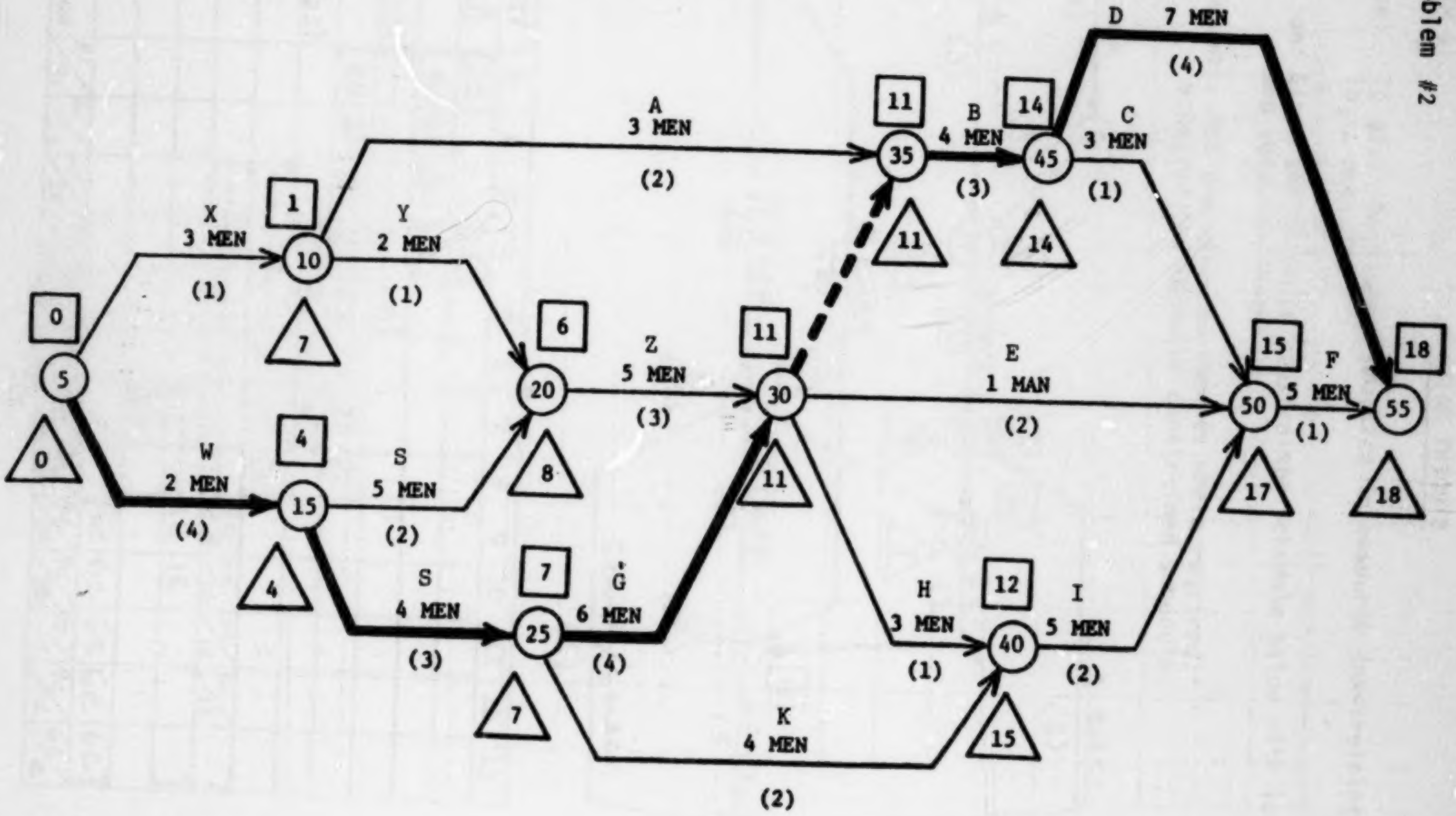

1
2 carp.
(1)
5
4
3
6 carp.
(3)
10
4
5 carp.
(3)
6
6
20
7
25
7
2 carp.
(1)
1 ELECT.
(2)
2 ELECT.
(8)
0
1
0
4 carp.
(2)
15
5
2 carp.
(3)
8
30
8
6 carp.
(5)
13
35
13
3 carp. / 1 ELECT.
(4)

ACTIVITY	1	2	3	4	5	6	7	8	9	10	11	12	13
1-5 (10)	[2c			☒]									
1-10	[6c	6c	6c	☒]									
1-15 (25)	[—	—	—	4c	4c]								
1-30	[2E	2E	2E	2E	2E	2E	2E	2E]					
10-20(25)				[5c	5c	5c	☒]						
15-30			[—	—	—	2c	2c	2c]					
15-35			[—	—	—	—	—	—	3c/1E	3c/1E	3c/1E	3c/1E	]
20-35							[—	—	1E	1E			]
25-30							[2c	]					
30-35									[6c	6c	6c	6c	6c]
Resources	8c/2E	6c/2E	6c/2E	9c/2E	9c/2E	7c/2E	4c/2E	2c/2E	9c/2E	9c/2E	9c/1E	9c/1E	6c/0

STUDENT NOTES

Problem #2

REQUIREMENT: Resource Constrain the schedule (Resource limit of 11 Men) and add the Resource Dummies to the logic network.


0
5
0
X
3 MEN
(1)
1
10
7
W
2 MEN
(4)
4
15
4
A
3 MEN
(2)
Y
2 MEN
(1)
S
5 MEN
(2)
S
4 MEN
(3)
6
20
8
7
25
7
Z
5 MEN
(3)
Ġ
6 MEN
(4)
K
4 MEN
(2)
11
30
11
11
35
11
B
4 MEN
(3)
14
45
14
D
7 MEN
(4)
C
3 MEN
(1)
E
1 MAN
(2)
H
3 MEN
(1)
12
40
15
I
5 MEN
(2)
15
50
17
F
5 MEN
(1)
18
55
18

```
****** EARLY START SCHEDULE FOLLOWS *******
```

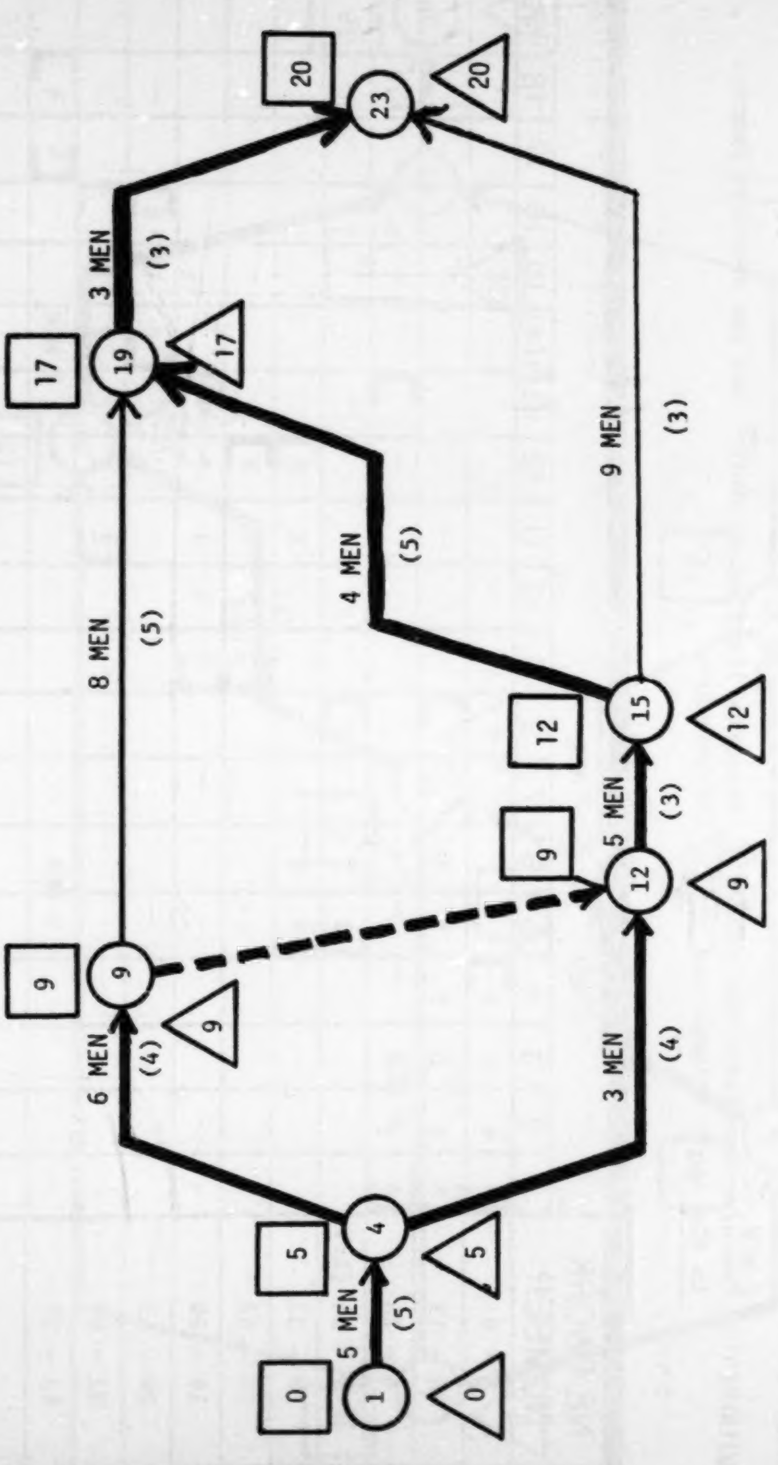
Problem #2

```
============|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|
            | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
============|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|
  5   - 10  | 3A | X  | X  | X  | X  | X  | X  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
* 5   - 15  | 2A | 2A | 2A | 2A |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
  10  - 20  |    | 2A | F  | F  | F  | F  | X  | X  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
  10  - 35  |    | 3A | 3A | F  | F  | F  | F  | F  | F  | F  | F  |    |    |    |    |    |    |    |    |    |    |    |
------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
  15  - 20  |    |    |    |    | 5A | 5A | X  | X  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
* 15  - 25  |    |    |    |    | 4A | 4A | 4A |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
  20  - 30  |    |    |    |    |    |    | 5A | 5A | 5A | F  | F  |    |    |    |    |    |    |    |    |    |    |    |
* ( 35    ) |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
* 25  - 30  |    |    |    |    |    |    |    | 6A | 6A | 6A | 6A |    |    |    |    |    |    |    |    |    |    |    |
* ( 35    ) |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
  25  - 40  |    |    |    |    |    |    |    | 4A | 4A | F  | F  | F  | X  | X  | X  |    |    |    |    |    |    |    |
------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
  30  - 40  |    |    |    |    |    |    |    |    |    |    |    | 3A | X  | X  | X  |    |    |    |    |    |    |    |
------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
  30  - 50  |    |    |    |    |    |    |    |    |    |    |    | 1A | 1A | F  | F  | X  | X  |    |    |    |    |    |
------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
* 35  - 45  |    |    |    |    |    |    |    |    |    |    |    | 4A | 4A | 4A |    |    |    |    |    |    |    |    |
------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
  40  - 50  |    |    |    |    |    |    |    |    |    |    |    |    | 5A | 5A | F  | X  | X  |    |    |    |    |    |
------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
  45  - 50  |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 3A | X  | X  |    |    |    |    |    |
------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
* 45  - 55  |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 7A | 7A | 7A | 7A |    |    |    |    |
------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
  50  - 55  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 5A | F  | F  |    |    |    |    |
============|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|
            | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
============|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|====|
RESOURCE TOTALS
A= MEN        5    7    5    2    9    9    9    15   15   6    6    8    10   9    10   12   7    7
```

PROBLEM #3.

REQUIREMENT: Resource constrain the schedule (resource limit of 12 men). Add the Resource Dummies to the logic network and update the schedule.

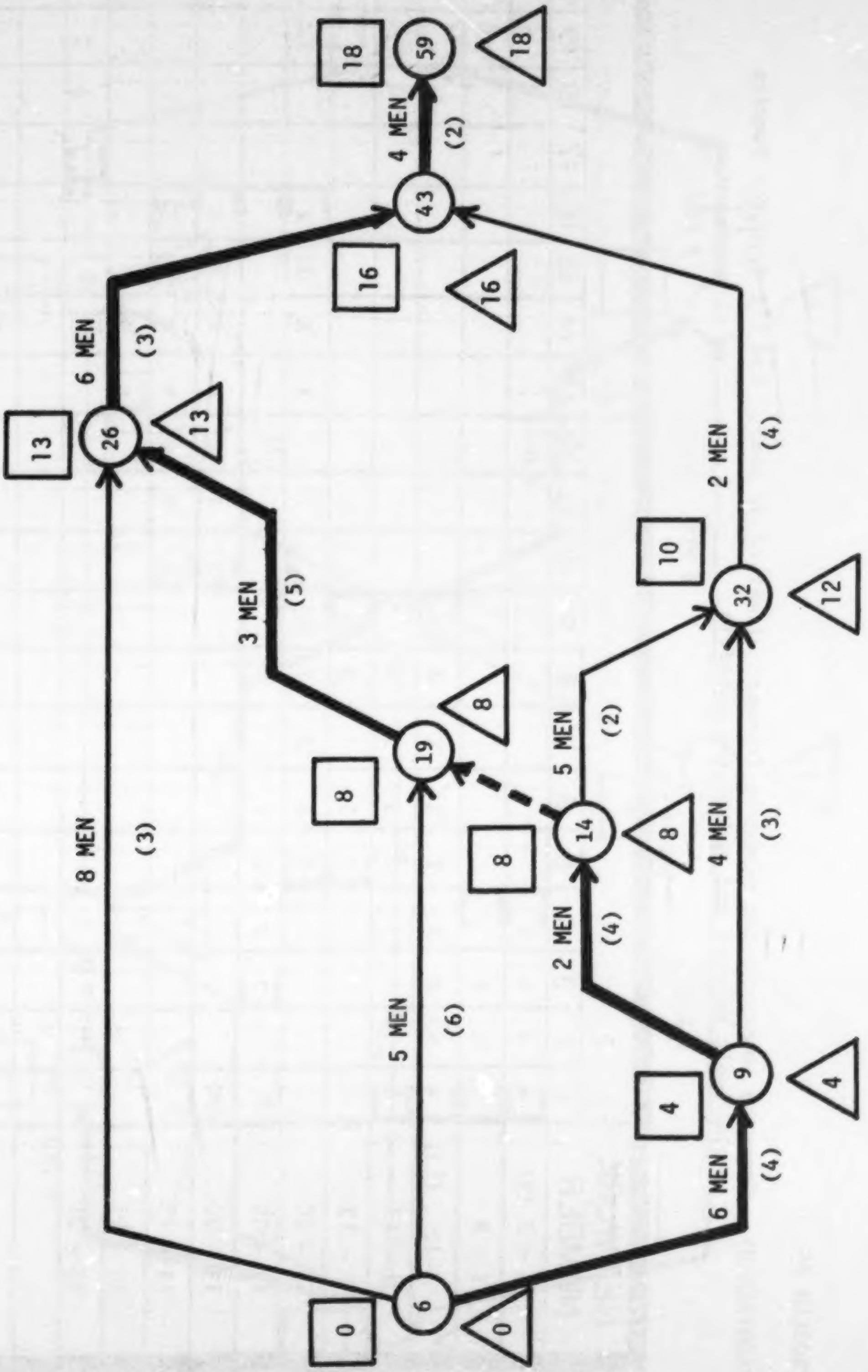
NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1 - 4	5	5	5	5	5															
4 - 9 (12)						6	6	6	6											
4 - 12						3	3	3	3											
9 - 19										8	8	8	8	8						
12 - 15										5	5	5								
15 - 19													4	4	4	4	4			
15 - 23													9	9	9					
19 - 23																		3	3	3
TOTAL	5	5	5	5	5	9	9	9	9	13	13	13	21	21	13	4	4	3	3	3


1
0
0
5 MEN
(5)
4
5
5
6 MEN
(4)
9
9
9
3 MEN
(4)
12
9
9
5 MEN
(3)
15
12
12
8 MEN
(5)
4 MEN
(5)
9 MEN
(3)
19
17
17
3 MEN
(3)
23
20
20

PROBLEM #4.

REQUIREMENT: Resource constrain the schedule (resource limit of 11 men). Add the Resource Dummies to the logic network and update the schedule.

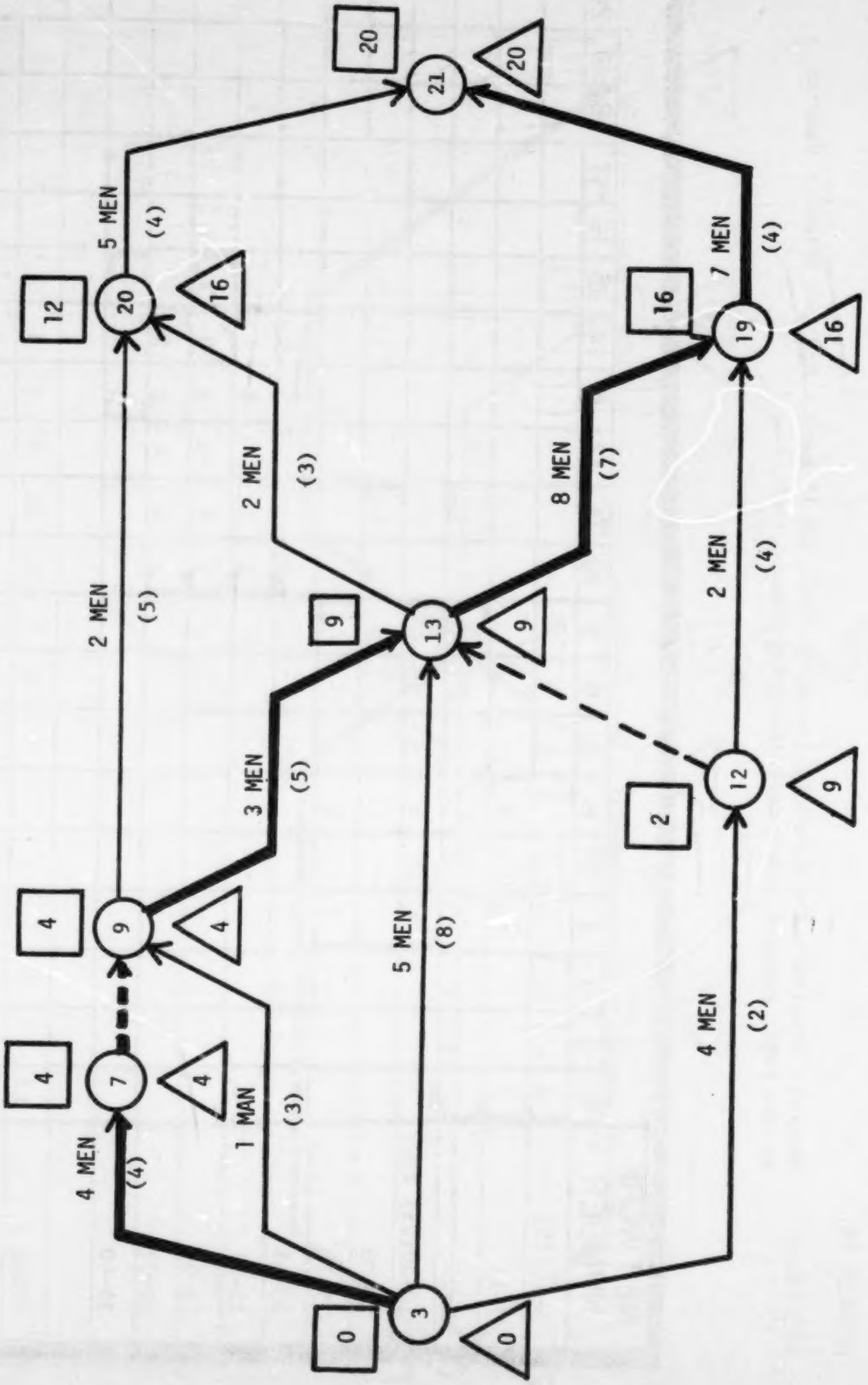
NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6 - 9	6	6	6	6																
6 - 19	5	5	5	5	5	5														
6 - 26	8	8	8																	
9 - 14 (19)					2	2	2	2												
9 - 32					4	4	4													
14 - 32											X	X								
19 - 26									5	5	X	X								
26 - 43									3	3	3	3	3							
32 - 43														6	6	6				
43 - 59											2	2	2	2						
																	4	4		
TOTAL	19	19	19	11	11	11	6	2	8	8	5	5	5	8	6	6	4	4		


6
0
0
6 MEN
(4)
9
4
4
5 MEN
(6)
8 MEN
(3)
2 MEN
(4)
14
8
8
4 MEN
(3)
19
8
8
5 MEN
(2)
3 MEN
(5)
32
10
12
26
13
13
2 MEN
(4)
6 MEN
(3)
43
16
16
4 MEN
(2)
59
18
18

PROBLEM #5.

REQUIREMENT: Resource constrain the schedule (resource limit of 12 men). Add the Resource Dummies to the logic network and update the schedule.

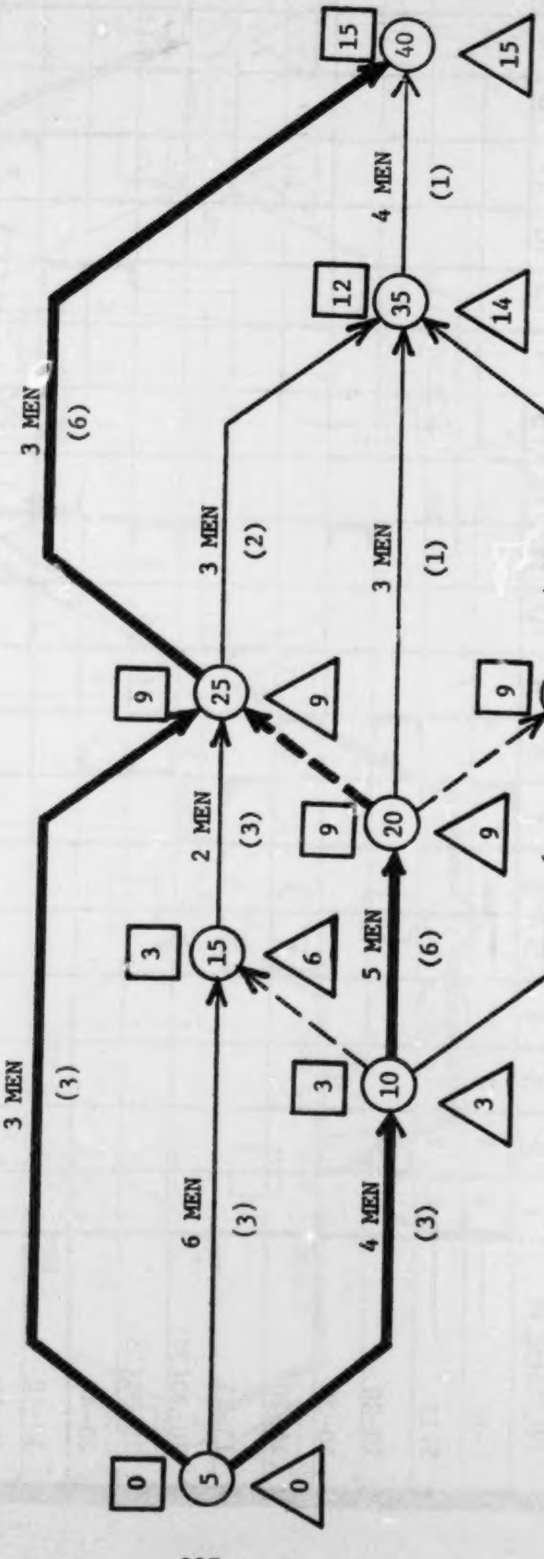
NETWORK NUMBER	1	2	3	4	5	6	7	8	9'	10	11	12	13	14	15	16	17	18	19	20
3 - 7 (9)	4	4	4	4																
3 - 9	1	1	1																	
3-12 (13)	4	4	X	X	X	X	X	X	X											
3 - 13	5	5	5	5	5	5	5	5												
9 - 13					3	3	3	3	3											
9 - 20					2	2	2	2	2				X	X	X	X				
12 - 19			2	2	2	2														
13 - 20										2	2	2	X	X	X	X				
13 - 19										8	8	8	8	8	8	8				
20 - 21													5	5	5	5				
19 - 21																	7	7	7	7
TOTAL	14	14	12	11	12	12	10	10	5	10	10	10	13	13	13	13	7	7	7	7


3
0
0
4 MEN
(4)
7
4
4
1 MAN
(3)
9
4
4
5 MEN
(8)
4 MEN
(2)
12
2
9
3 MEN
(5)
13
9
9
2 MEN
(5)
2 MEN
(3)
8 MEN
(7)
2 MEN
(4)
20
12
16
5 MEN
(4)
19
16
16
7 MEN
(4)
21
20
20

PROBLEM #6.

REQUIREMENT: Resource constrain the schedule (resource limit of 10 men). Add the Resource Dummies to the logic network and update the schedule.

NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5-10(15)	4	4	4																	
5-15	6			X	X	X														
5-25	3	3	3																	
10-20(25) (30)				5	5	5	5	5	5											
10-30										X	X									
15-25				2	2	2														
20-35										3			X	X						
25-35										3	3		X	X						
25-40										3	3	3	3	3	3					
30-35										4	4	4	X	X						
35-40													4							
TOTAL	13	7	7	7	7	7	5	5	5	13	10	7	7	3	3					

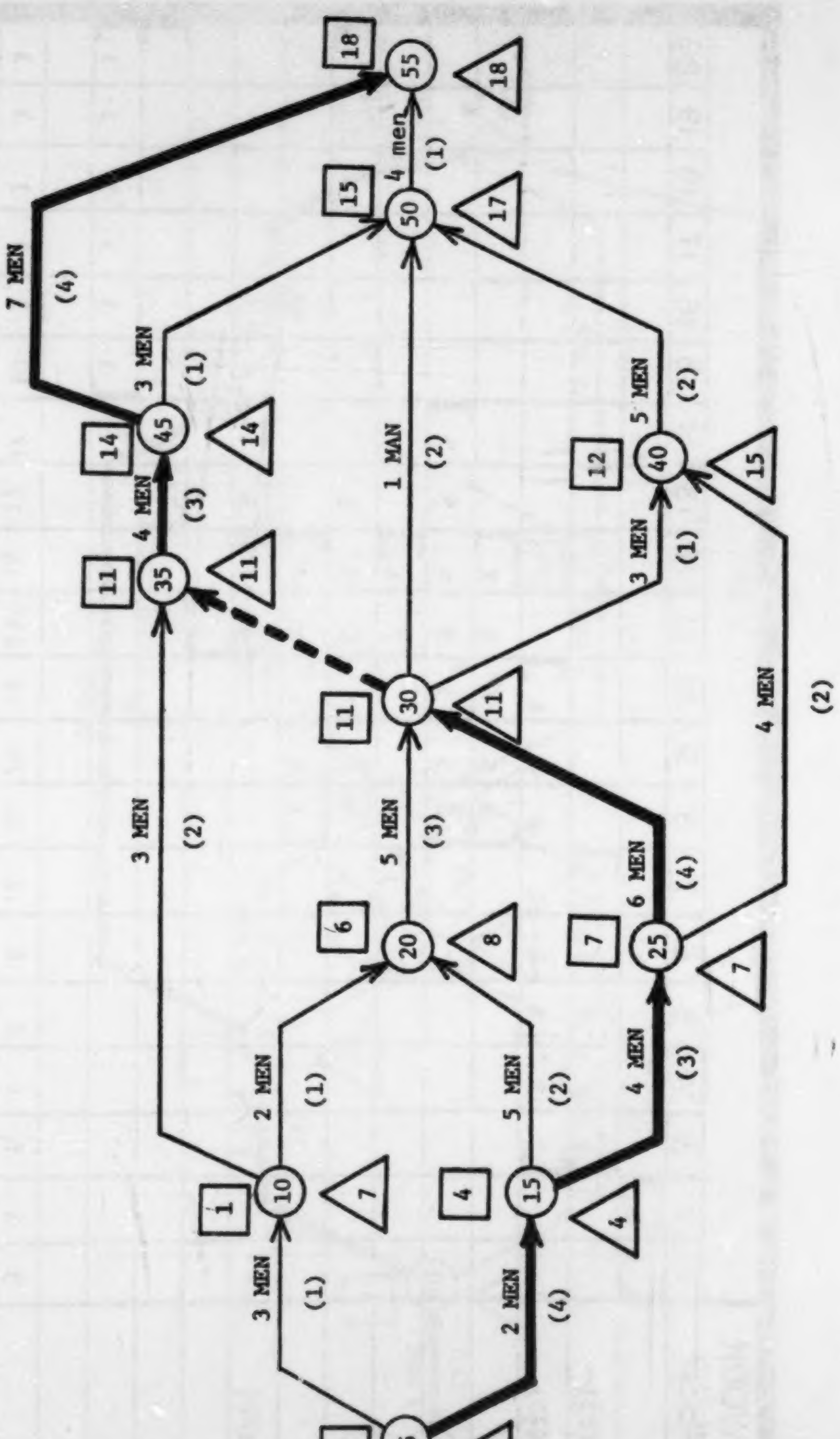


5
0
0
10
3
3
15
3
6
20
9
9
25
9
9
30
9
11
35
12
14
40
15
15
3 MEN
(3)
6 MEN
(3)
4 MEN
(3)
2 MEN
(3)
5 MEN
(6)
6 men
(2)
3 MEN
(6)
3 MEN
(2)
3 MEN
(1)
4 MEN
(3)
4 MEN
(1)

PROBLEM #7.

REQUIREMENT: Resource constrain the schedule (resource limit of 11 men). Add the Resource Dummies to the logic network and update the schedule.

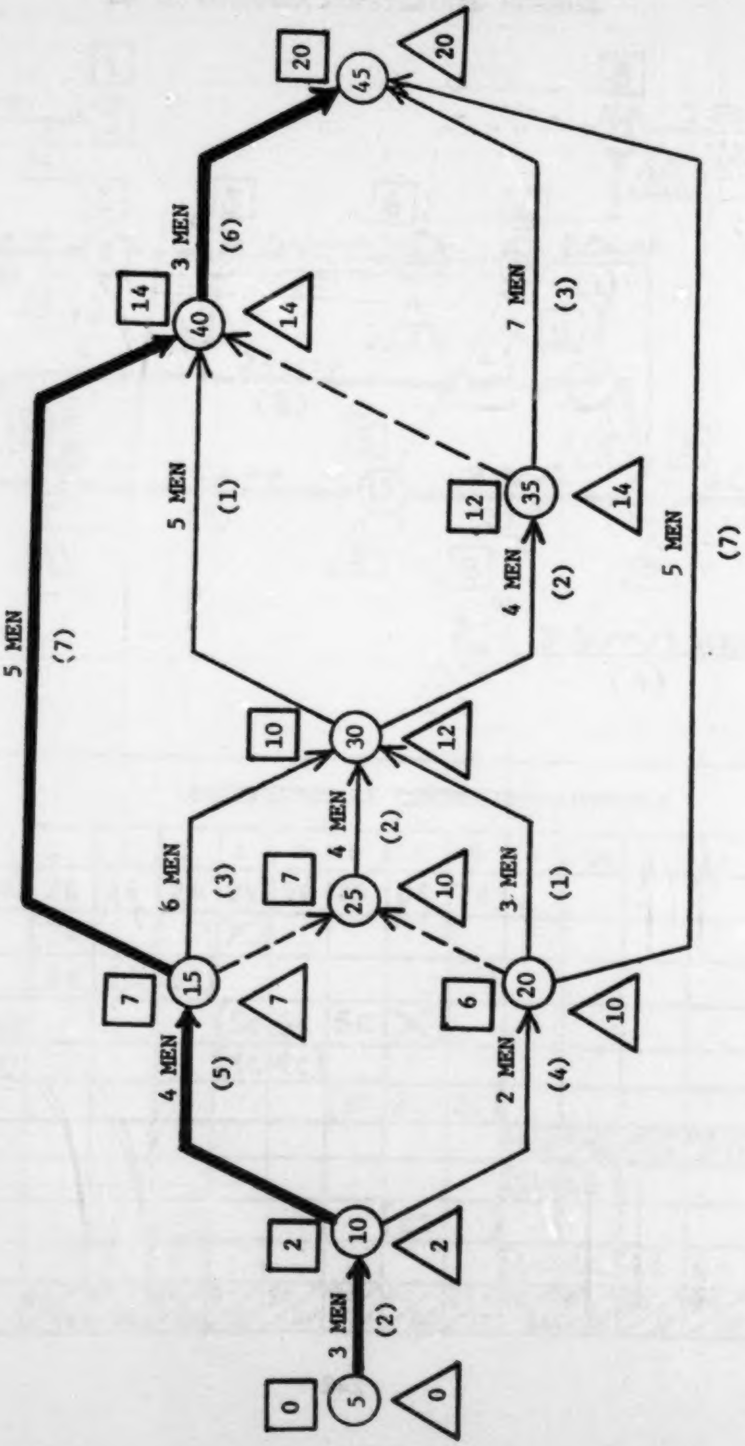
NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5–10	3	X	X	X	X	X	X													
5–15	2	2	2	2																
10–20		2					X	X												
10–35		3	3																	
15–20					5	5	X	X												
15–25					4	4	4													
20–30(35)							5	5	5											
25–30(35)								6	6	6	6									
25–40								4	4											
30–40													X	X	X					
30–50												3	X	X	X					
35–45												1	1			X	X			
40–50												4	4	4						
45–50													5	5		X	X			
45–55															3	X	X			
50–55															7	7	7	7		
																4				
TOTAL	5	7	5	2	9	9	9	15	15	6	6	8	10	9	10	11	7	7		


5
0
0
3 MEN
(1)
2 MEN
(4)
10
1
7
15
4
4
2 MEN
(1)
5 MEN
(2)
4 MEN
(3)
3 MEN
(2)
20
6
8
25
7
7
5 MEN
(3)
6 MEN
(4)
4 MEN
(2)
30
11
11
35
11
11
4 MEN
(3)
1 MAN
(2)
3 MEN
(1)
45
14
14
40
12
15
3 MEN
(1)
5 MEN
(2)
7 MEN
(4)
50
15
17
4 men
(1)
55
18
18

PROBLEM #8.

REQUIREMENT: Resource constrain the schedule (resource limit of 15 men). Add the Resource Dummies to the logic network and update the schedule.

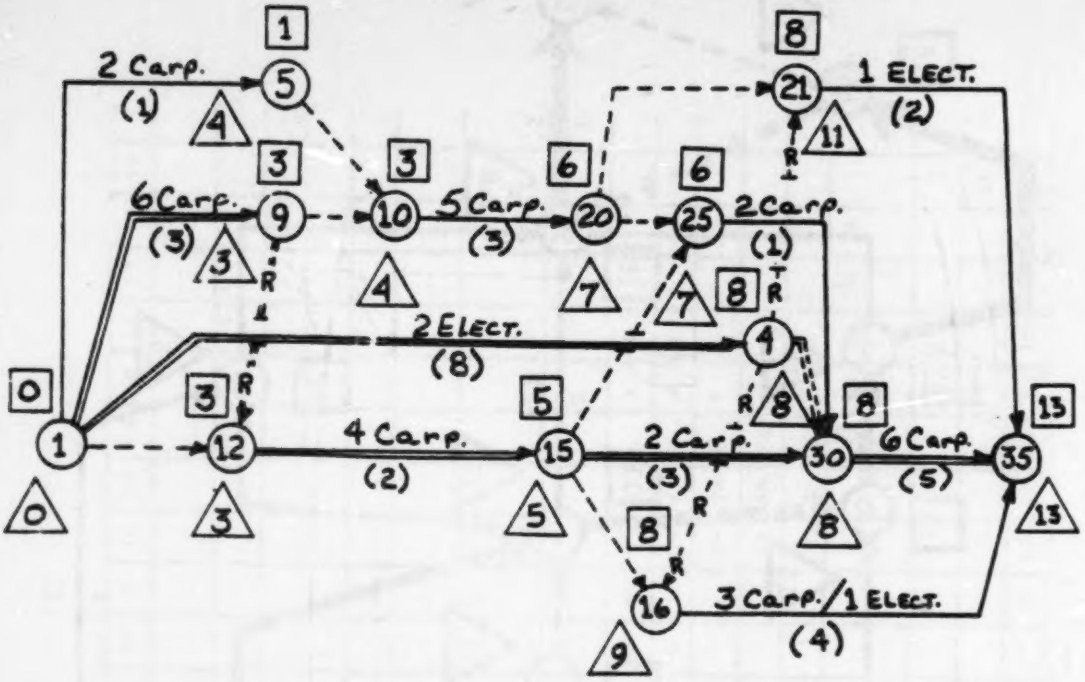
NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5-10	3	3																		
10-15(25)			4	4	4	4	4													
10-20(25)			2	2	2	2	X	X	X	X										
15-30								6	6	6	X	X								
15-40								5	5	5	5	5	5	5						
20-30							3				X	X								
29-45							5	5	5	5	5	5	5							
25-30								4	4		X	X								
30-35(40)											4	4	X	X						
30-40											5									
35-45													7	7	7					
40-45															3	3	3	3	3	3
TOTAL	3	3	6	6	6	6	12	20	20	16	14	14	17	12	10	3	3	3	3	3


5
0
0
3 MEN
(2)
10
2
2
4 MEN
(5)
2 MEN
(4)
15
7
7
20
6
10
5 MEN
(7)
6 MEN
(3)
3 MEN
(1)
25
7
10
4 MEN
(2)
30
10
12
5 MEN
(1)
4 MEN
(2)
35
12
14
5 MEN
(7)
40
14
14
7 MEN
(3)
3 MEN
(6)
45
20
20

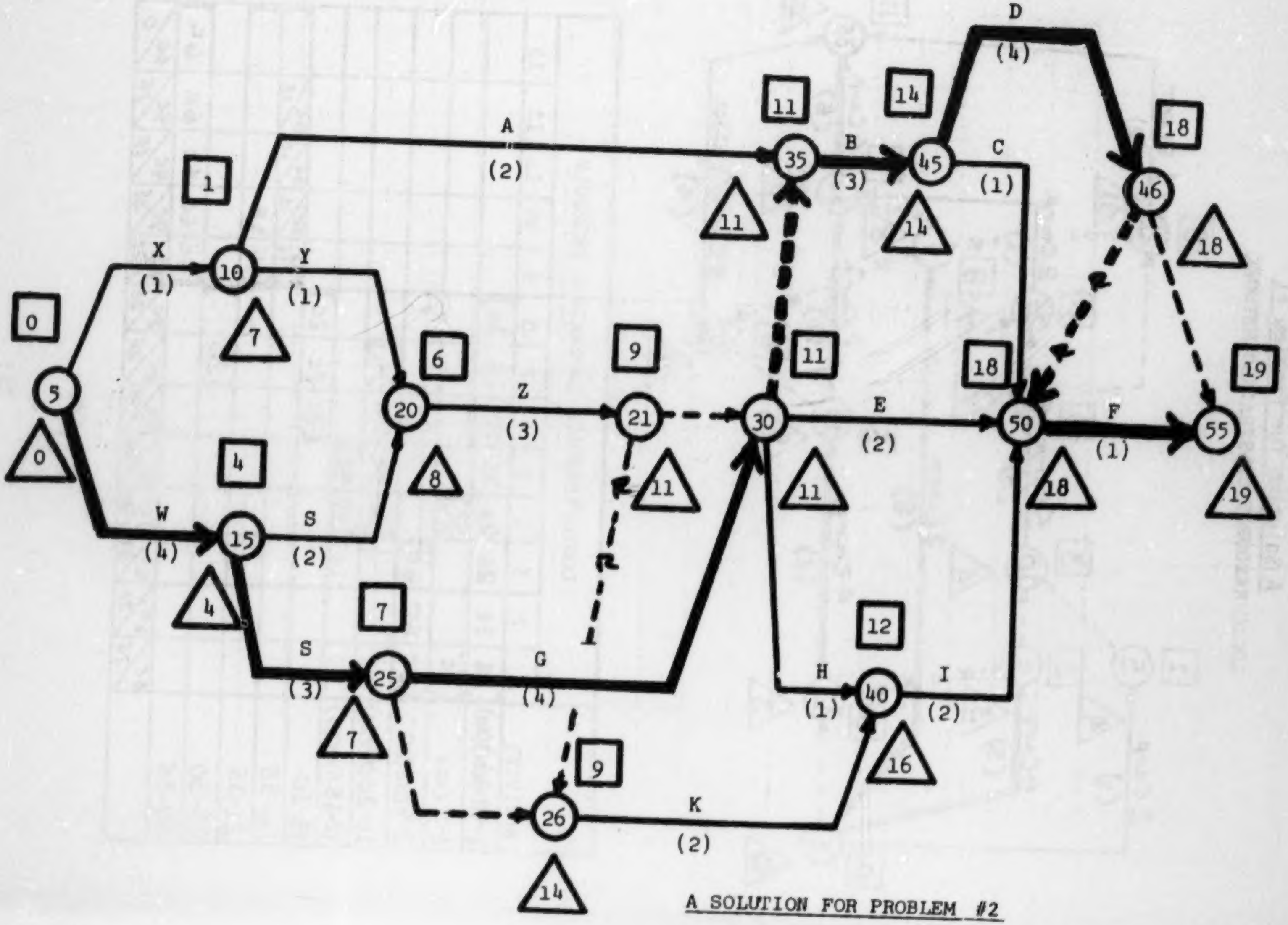
STUDENT NOTES

A Solution for Problem #1

LOGIC/RESOURCE CONSTRAINED NETWORK


2 Carp. (1)
6 Carp. (3)
5 Carp. (3)
2 Carp. (1)
1 Elect. (2)
2 Elect. (8)
4 Carp. (2)
2 Carp. (3)
6 Carp. (5)
3 Carp./1 Elect. (4)
R
1
5
9
10
20
21
25
4
12
15
16
30
35
0
3
4
6
7
8
11
13
9

ACTIVITY	LOGIC/RESOURCE CONTRAINED SCHEDULE												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1-4(16)(21)(30)	[2E	2E	2E	2E	2E	2E	2E	2E]					
1-5 (10)	[2C			X]									
1-9(10)(12)	[6C	6C	6C]										
10-20(21)(25)				[5C	5C	5C	X]						
12-15(16)(25)				[4C	4C]								
15-30						[2C	2C	2C]					
16-35									3C/1E	3C/1E	3C/1E	3C/1E	]
21-35									[1E	1E			]
25-30							[2C	]					
30-35									[6C	6C	6C	6C	6C]
	8C/2E	6C/2E	6C/2E	9C/2E	9C/2E	7C/2E	4C/2E	2C/2E	9C/2E	9C/2E	9C/1E	9C/1E	6C/0

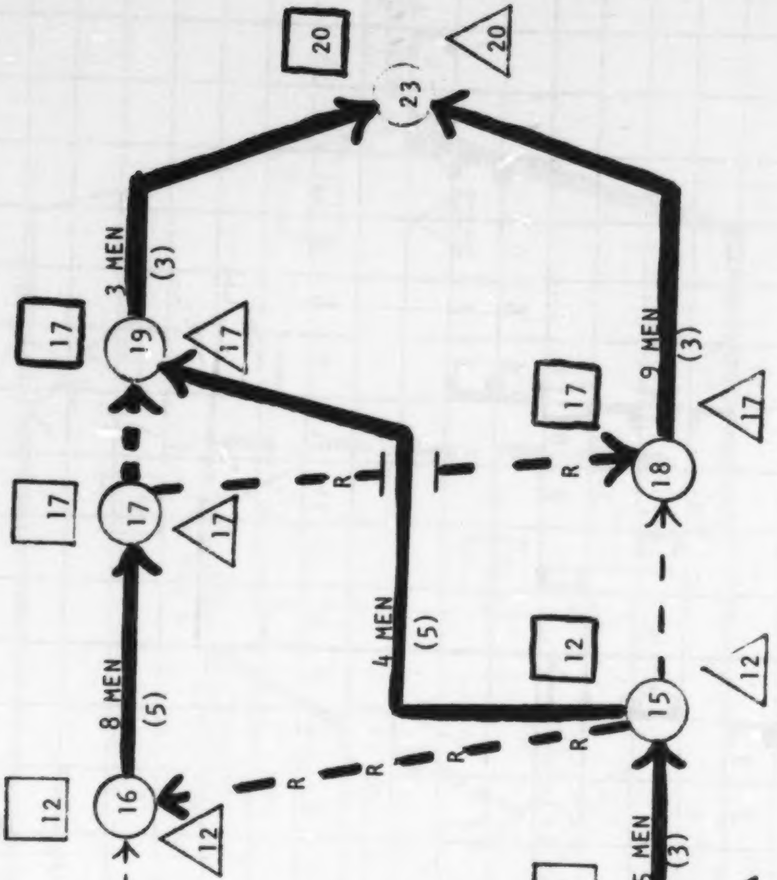

0
5
0
X
(1)
10
1
7
W
(4)
15
4
4
A
(2)
Y
(1)
S
(2)
20
6
8
S
(3)
25
7
7
Z
(3)
21
9
11
G
(4)
26
9
14
K
(2)
30
11
11
35
11
11
B
(3)
45
14
14
D
(4)
46
18
18
C
(1)
E
(2)
H
(1)
40
12
16
I
(2)
50
18
18
F
(1)
55
19
19

A SOLUTION FOR PROBLEM #2

A Solution for Problem #2

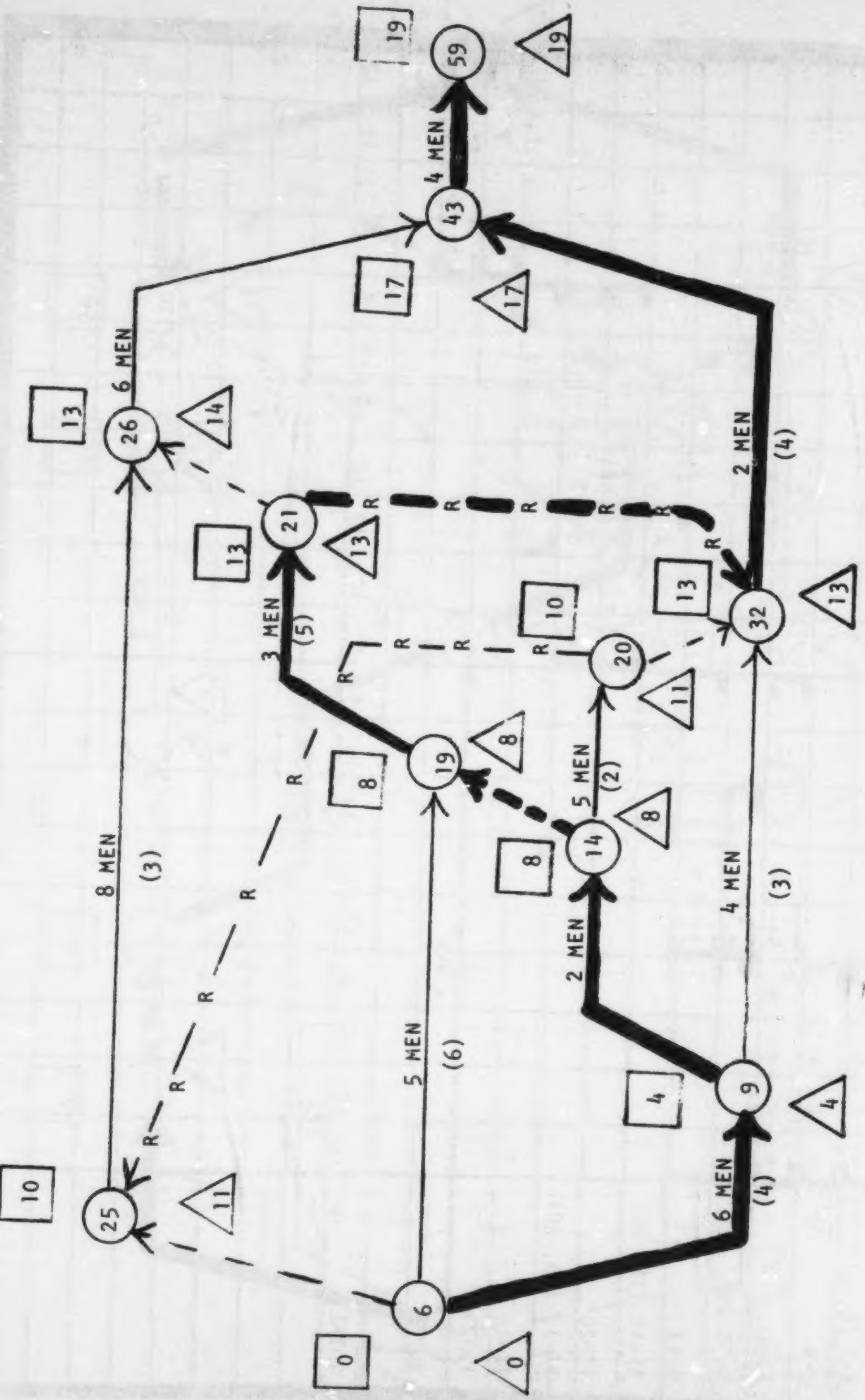
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
5 - 10	3A	X	X	X	X	X	X												
* 5 - 15	2A	2A	2A	2A															
10 - 20		2A	F	F	F	F	X	X											
10 - 35		3A	3A	F	F	F	F	F	F	F	F								
15 - 20					5A	5A	X	X											
* 15 - 25 (26)					4A	4A	4A												
20 - 21 (26)R (30)							5A	5A	5A	X	X								
* 25 - 30 * (35)								6A	6A	6A	6A								
26 - 40										4A	4A	F	X	X	X	X			
30 - 40												3A	X	X	X	X			
30 - 50												1A	1A	F	F	F	F	F	
* 35 - 45												4A	4A	4A					
40 - 50													5A	5A	F	F	F	F	
* 45 - 46 * (50)R (55)															7A	7A	7A	7A	
45 - 50															3A	F	F	F	
* 50 - 55																			5A
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
RESOURCE TOTALS A= MEN	5	7	5	2	9	9	9	11	11	10	10	8	10	9	10	7	7	7	5

NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1-4	5	5	5	5	5															
4-9 (12, 16)						6	6	6	6											
4-12						3	3	3	3											
12-15 (16, 18)																				
15-19										5	5	5								
16-17 (18, 19)													4	4	4	4	4			
18-23													8	8	8	8	8			
19-23																		9	9	9
																		3	3	3
TOTAL	5	5	5	5	5	9	9	9	9	5	5	5	12	12	12	12	12	12	12	12


1
5 MEN
(5)
4
6 MEN
(4)
3 MEN
(4)
9
12
5 MEN
(3)
15
16
8 MEN
(5)
4 MEN
(5)
17
18
19
9 MEN
(3)
3 MEN
(3)
23
R
R
R
R
R
R
0
0
5
5
9
9
9
9
12
12
12
12
17
17
17
17
17
17
20
20

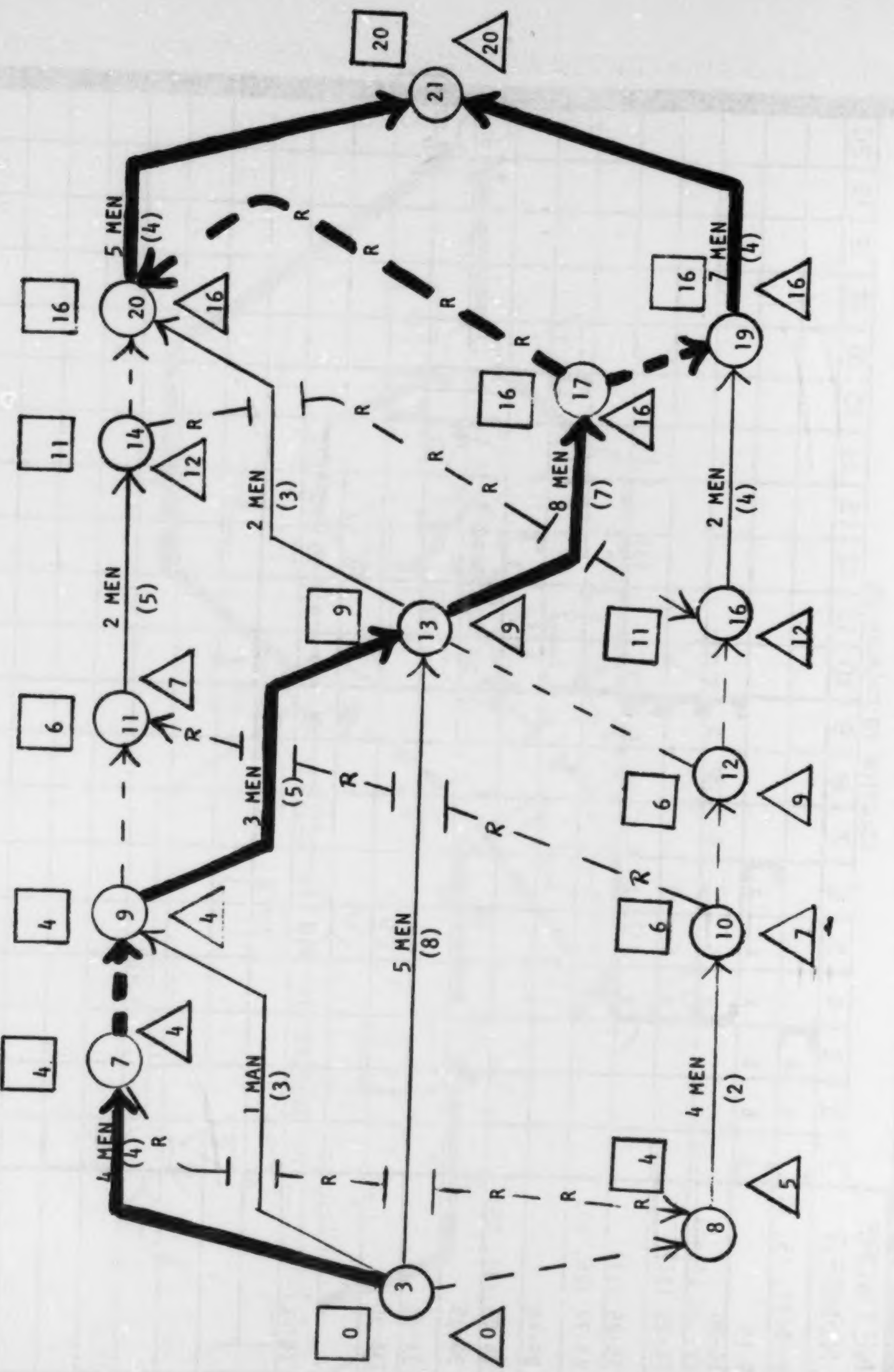
SOLUTION TO PROBLEM #4

NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6-9	6	6	6	6																
6-19	5	5	5	5	5	5														
9-14 (19)					2	2	2	2												
9-32					4	4	4													
14-20 (25, 32)									5	5	X									
19-21 (26, 32)									3	3	3	3	3							
25-26											8	8	8	X						
26-43														6	6	6				
32-43														2	2	2	2			
43-59																		4	4	
TOTAL	11	11	11	11	11	11	6	2	8	8	11	11	11	8	8	8	2	4	4	


6
0
0
6 MEN
(4)
9
4
4
5 MEN
(6)
25
10
11
R
R
R
R
R
8 MEN
(3)
26
13
14
6 MEN
2 MEN
14
8
8
5 MEN
(2)
19
8
8
20
10
11
R
R
R
R
3 MEN
(5)
21
13
13
R
R
R
R
R
R
4 MEN
(3)
32
13
13
2 MEN
(4)
43
17
17
4 MEN
59
19
19

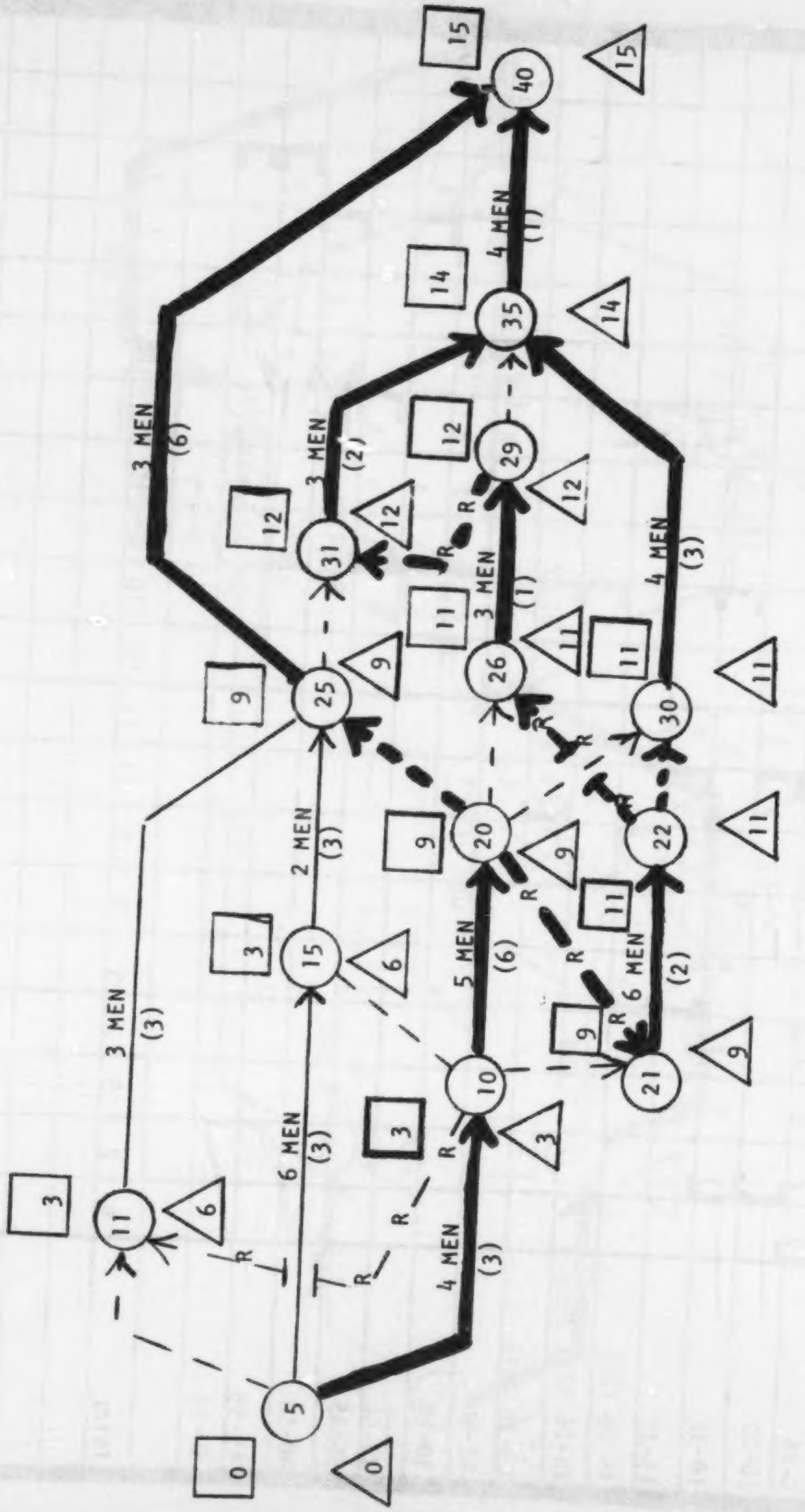
SOLUTION TO PROBLEM #5

NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
3-7 (8, 9)	4	4	4	4																
3-9	1	1	1																	
3-13	5	5	5	5	5	5	5	5												
8-10 (11, 12)					4	4	X													
9-13					3	3	3	3	3											
11-14 (16, 20)							2	2	2	2	2	X								
13-20										2	2	2	X	X	X	X				
13-17 (19, 20)										8	8	8	8	8	8	8				
16-19.												2	2	2	2					
19-21																	7	7	7	7
20-21																	5	5	5	5
TOTAL	10	10	10	9	12	12	10	10	5	12	12	12	10	10	10	8	12	12	12	12


4 MEN
(4)
1 MAN
(3)
5 MEN
(8)
4 MEN
(2)
3 MEN
(5)
2 MEN
(5)
2 MEN
(3)
8 MEN
(7)
2 MEN
(4)
7 MEN
(4)
5 MEN
(4)
R

SOLUTION TO PROBLEM #6

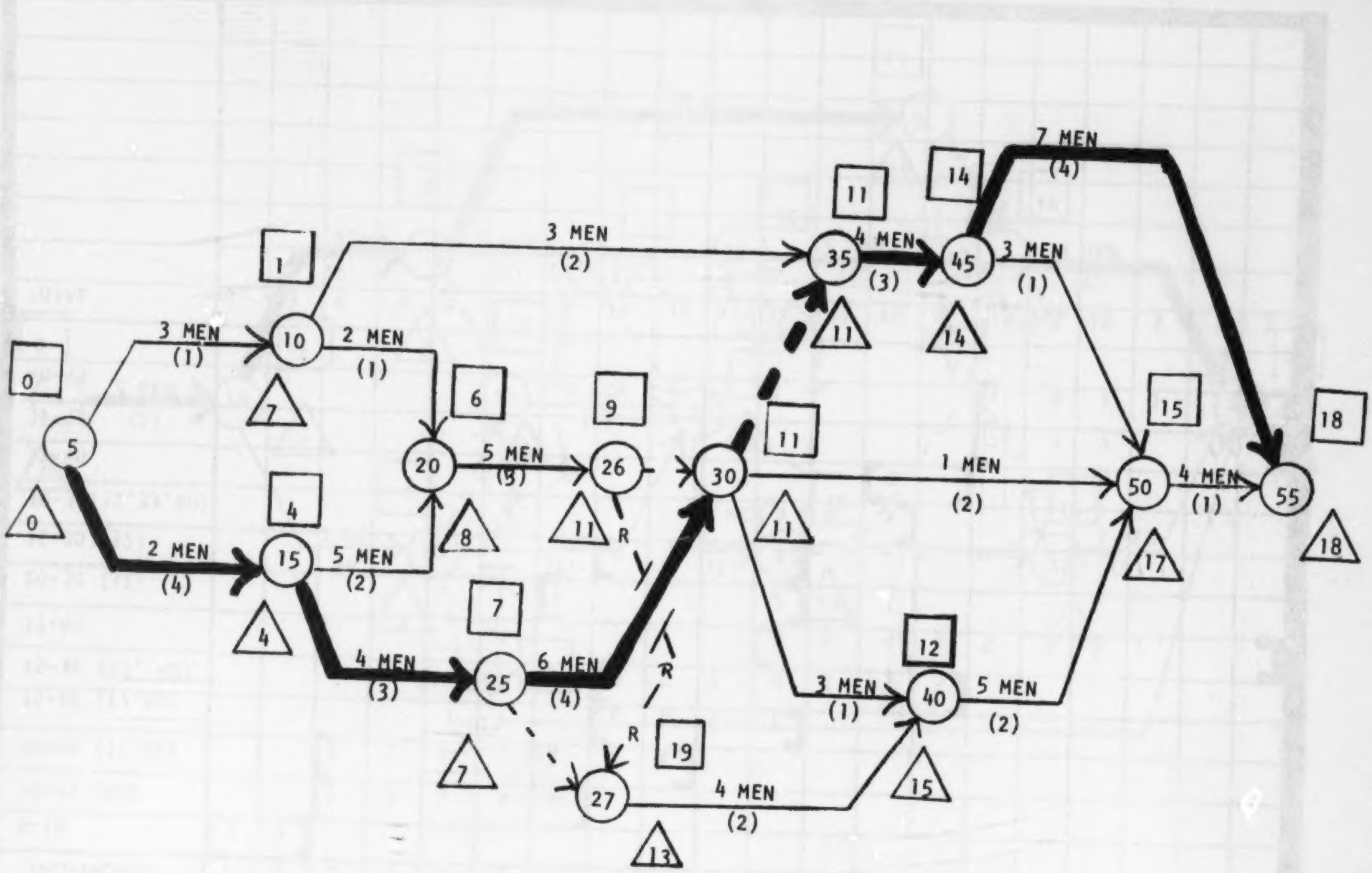
NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5-10(11, 15, 21)	4	4	4																	
5-15	6	6	6	x	x	x														
10-20 (21,25,26,30)				5	5	5	5	5	5											
11-25 (31)				3	3	3														
15-25 (31)				2	2	2														
21-22 (26, 30)										6	6									
25-40										3	3	3	3	3	3					
26-29 (31, 35)												3								
30-35												4	4	4						
31-35													3	3						
35-40															4					
TOTAL	10	10	10	10	10	10	5	5	5	9	9	10	10	10	7					



0
0
5
4 MEN
(3)
6 MEN
(3)
R
R
R
R
11
3
6
3 MEN
(3)
10
3
3
15
3
6
2 MEN
(3)
5 MEN
(6)
6 MEN
(2)
R
R
R
20
9
9
21
9
9
22
11
11
25
9
9
3 MEN
(6)
26
11
11
3 MEN
(1)
30
11
11
R
R
R
31
12
12
3 MEN
(2)
R
R
29
12
12
4 MEN
(3)
35
14
14
4 MEN
(1)
40
15
15

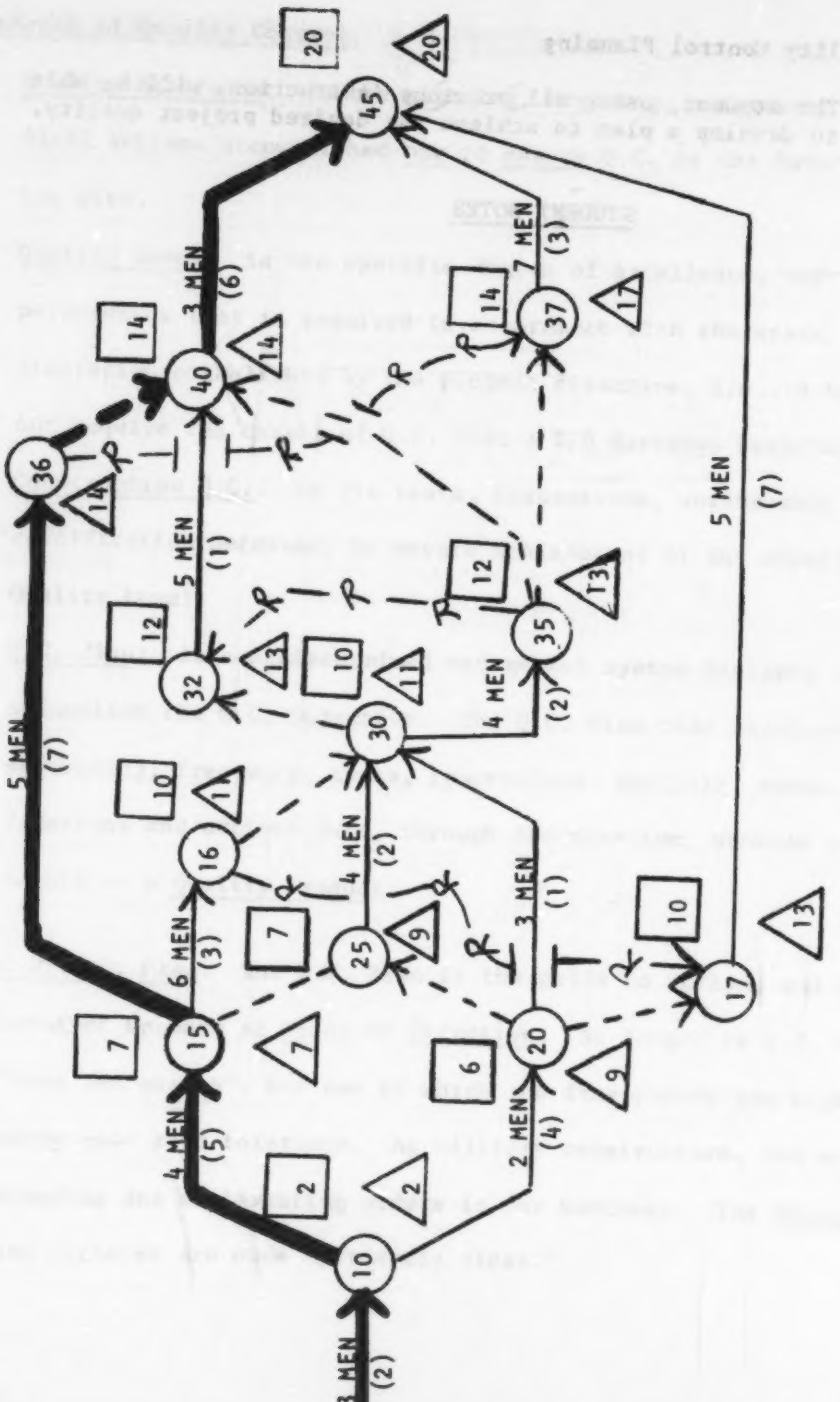
SOLUTION TO PROBLEM #7

NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5-10	3	X	X	X	X	X	X													
5-15	2	2	2	2																
10-20		2					X	X												
10-35		3	3																	
15-20					5	5	X	X												
15-25 (27)					4	4	4													
20-26 (27, 30)							5	5	5	X	X									
25-30 (35)								6	6	6	6									
27-40										4	4		X	X	X					
30-40												3	X	X	X					
30-50												1	1			X	X			
35-45												4	4	4						
40-50															3	X	X			
45-55															7	7	7	7		
50-55																4				
TOTAL	5	7	5	2	9	9	9	11	11	10	10	8	10	9	10	11	7	7		


3 MEN (1)
2 MEN (4)
3 MEN (2)
2 MEN (1)
5 MEN (2)
4 MEN (3)
5 MEN (3)
6 MEN (4)
4 MEN (2)
4 MEN (3)
3 MEN (1)
1 MEN (2)
3 MEN (1)
5 MEN (2)
7 MEN (4)
4 MEN (1)
R
R
R

SOLUTION TO PROBLEM #8

NETWORK NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5-10	3	3																		
10-15 (25)			4	4	4	4	4													
10-20 (17,25)			2	2	2	2	X	X	X											
15-16 (17,30)								6	6	6	X									
15-36 (37, 40)								5	5	5	5	5	5	5						
17-45											5	5	5	5	5	5	5			
20-30 (32)							3				X									
25-30 (32)								4	4		X									
30-35(32,37,40)											4	4	X							
32-40													5							
37-45															7	7	7			
40-45															3	3	3	3	3	3
TOTAL	3	3	6	6	6	6	7	15	15	11	14	14	15	10	15	15	15	3	3	3



3 MEN
(2)
4 MEN
(5)
2 MEN
(4)
6 MEN
(3)
4 MEN
(2)
3 MEN
(1)
5 MEN
(7)
4 MEN
(2)
5 MEN
(1)
7 MEN
(3)
3 MEN
(6)
5 MEN
(7)
R

LESSON: Quality Control Planning

OBJECTIVE: The student, using all previous instruction, will be able to develop a plan to achieve the desired project quality.

STUDENT NOTES

Elements of Quality Control.

a. Quality Assurance: is the planning, training, management and technical actions accomplished now tc assure Q.C. in the future on the job site.

b. Quality Level: is the specific degree of excellence, and manning performance that is required in accordance with the specs, and time limitation established by the project directive, i.e., a bunker does not require the extent of Q.C. that a T/O Barracks building requires.

c. Construction Q.C.: is the tests, inspections, workmanship and certification necessary to assure achievement of the specified Quality Level.

d. Q.C. Plan: is a predetermined management system designed to accomplish the Q.C. objective. The Q.C. Plan ties together sequencing, frequency, types, inspections, analysis, areas, specifications and actions that, through coordination, provide the end result -- a Quality Product.

Scope of Q.C. Plan: The Q.C. Plan is the guide to action, and if signed by the Commander becomes an Order or Directive. No longer is Q.C. a nebulous area of "seek and search", but one in which the fine points are highlighted and demanding near zero tolerance. As military constructors, the essence of comprehending and implementing orders is our business. The Management's desires and dictates are made "perfectly clear."

METHODOLOGY: The Q.C. Plan should be developed during the preconstruction steps paralleling the Preliminary and Detailed Planning using the Critical Path Method. Consideration should be given to "centralized planning and decentralized execution."

OBJECTIVE OF QUALITY CONTROL:

Basic Steps in Quality Controlling:

a. Establish standards.

b. Compare actual results with established results.

c. Take corrective action.

d. Management by exception.

TRENDS IN NETWORK ANALYSIS

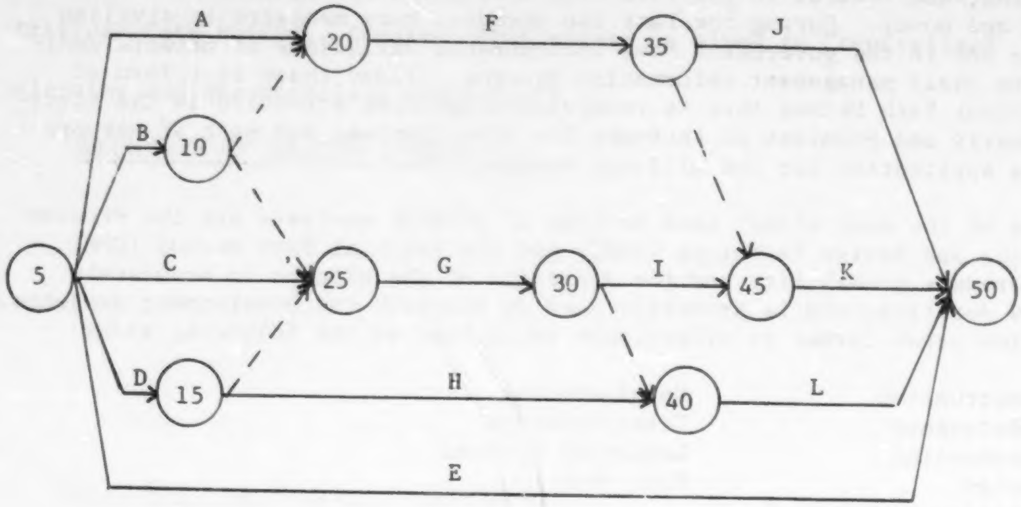
The marriage of network analysis techniques and computers for planning, scheduling, and control in the late 1950's resulted in significant savings in time and money. During the last two decades, many managers in civilian industry and in the government have incorporated variations of network analysis into their management information systems. Today there is a form of the Critical Path Method that is receiving widespread attention in the civilian industry and promises to increase the effectiveness and ease of network analysis application for the military manager.

Two of the most widely used methods of network analysis are the Program Evaluation and Review Technique (PERT) and the Critical Path Method (CPM). PERT addresses probability and the inability of the planner to accurately estimate durations and is primarily used in Research and Development projects. CPM in the arrow format is effectively being used in the following areas:

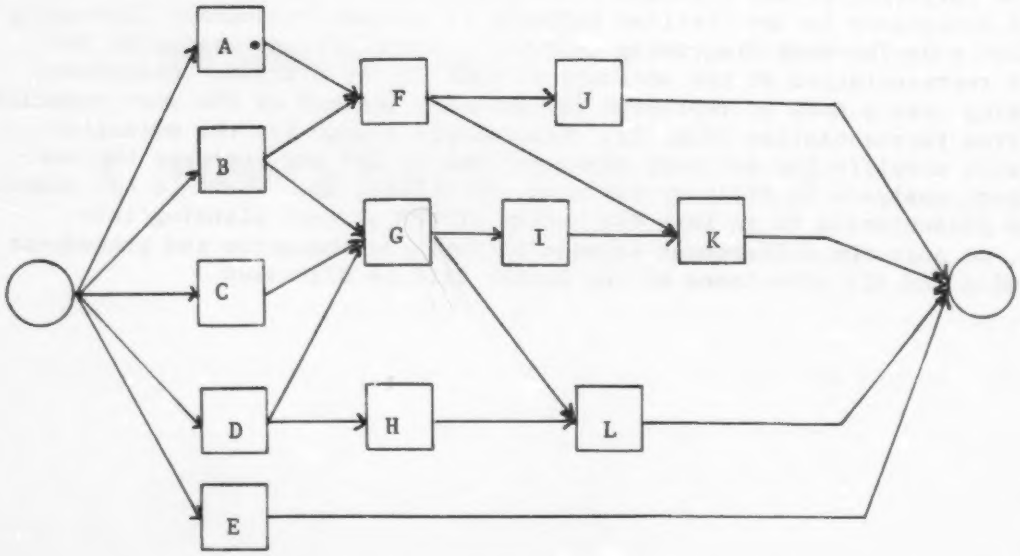
Construction
Maintenance
Warehousing
Design
Military Combat Tasks
Manufacturing
Transportation
Logistics Systems
Book Writing

hese applications are not limited to the civilian sector but are part of he planning in many government agencies. The U.S. Army Engineer School as taught CPM to the Engineer Officer and Advanced NCO courses since the iddle 1960's.

The variation of the Critical Path Method that is receiving the in- reased acceptance in the civilian industry is called 'Precedence Diagraming' r Activity-On-The-Node diagraming (A.O.N.). A significant change is the raphic representation of the activity or task in the diagram. Precedence iagraming uses a node to represent the activity instead of the most commonly en arrow representation (fig. 1). This simple change has the potential greatly simplify the military planners' use of CPM and increase the use network analysis in military planning and scheduling. There is not space this presentation to go into the basics of CPM project planning tech- ques, so only the differences between activity-on-the-arrow and precedence agraming and the advantages of the latter will be discussed.


A
F
J
20
35
B
10
5
C
25
G
30
I
45
K
50
D
15
H
40
L
E

ARROW FORMAT


A
F
J
B
G
I
K
C
D
H
L
E

NODE FORMAT

Figure 1

DIAGRAM DEVELOPMENT

The precedence diagram uses a node to represent the activity instead of an arrow. The precedence arrow is used as a connector like the event node in activity-on-the-arrow diagraming (fig. 2).

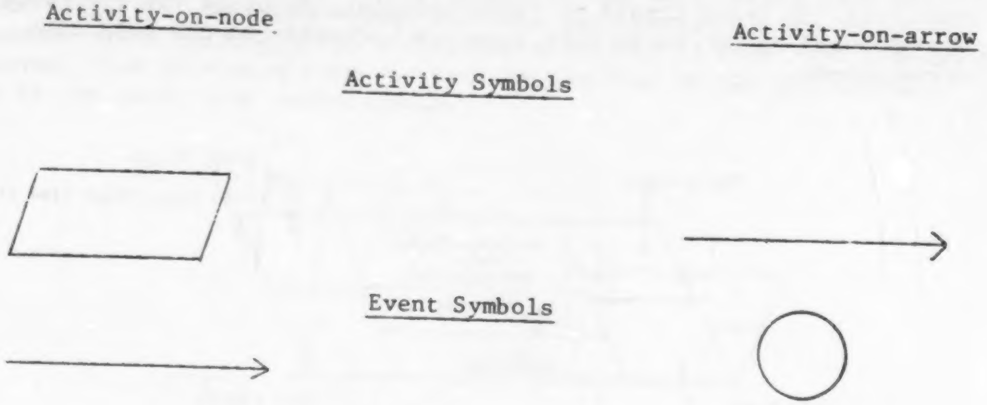


Figure 2.

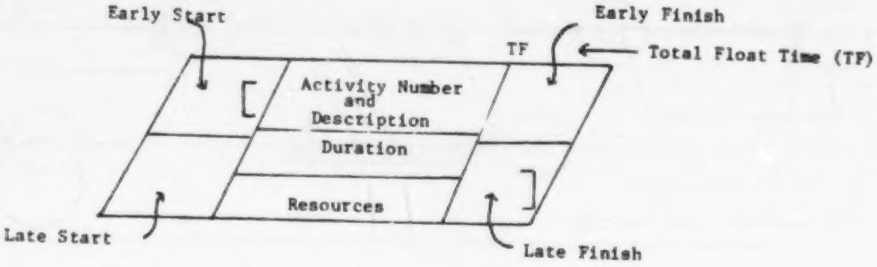
A major advantage to the military planner is that the node format readily lends itself to the use of preprinted gummed labels which can be typed. This will allow the elimination of extensive, time-consuming lettering and drafting. The diagram can be corrected by simply placing a new node over the old one or adding nodes and arrows as necessary.

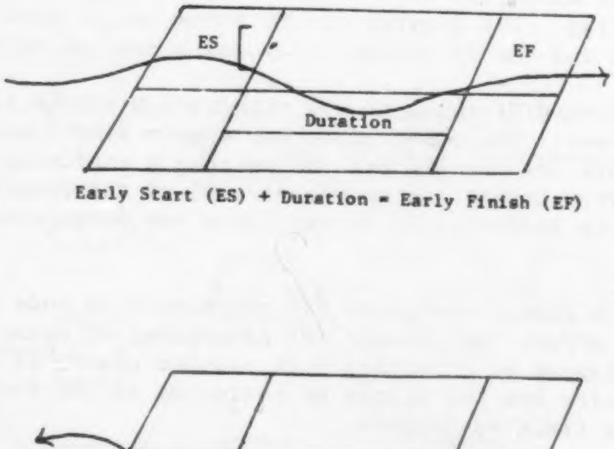
Another important difference is the elimination of the logic and numbering dummy arrows. The dummy arrow has always been a source of possible logic errors for the planner and extremely confusing to the field foreman. In the arrow format, approximately 30% of the diagram is normally dummy arrows and this profusion of dotted lines has overwhelmed many potential users.

This relatively simple change to the precedence or node format of network diagraming offers the planner the advantages of being able to quickly create a diagram of a project with reduced chance of error, and the completed graphics are not nearly as confusing to the field personnel who need to use the finished product.

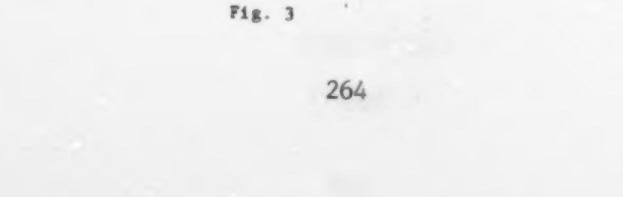
SCHEDULE DEVELOPMENT

The mechanics of the diagram time analysis are exactly the same for both formats. The grouping of all the data for an activity in one place in the node method greatly reduces the probability for the simple math errors that occur using the arrow format. The design of the proposed node (fig. 3) lends itself to rapid calculations since the eye tends to lean forward on the early time pass and backwards on the late time calculations.


Early Start
Early Finish
TF
Total Float Time (TF)
Activity Number and Description
Duration
Resources
Late Start
Late Finish


ES
EF
Duration

Early Start (ES) + Duration = Early Finish (EF)


Duration
LS
LF

Late Finish (LF) - Duration = Late Start (LS)

Fig. 3

The time analysis calculations are done according to the following general rules

a. Early Finish (EF) time = Early Start (ES) time + Activity Duration.

b. If more than one connecting arrow ends at a node, use the largest Early Finish time at the tail of the arrows as the Early Start time for the node (fig. 4). In other words, the work represented by the activity node cannot start until all the activities preceding it have been completed. The general flow is always from the tail to the head of the connecting arrows in the early time calculations.

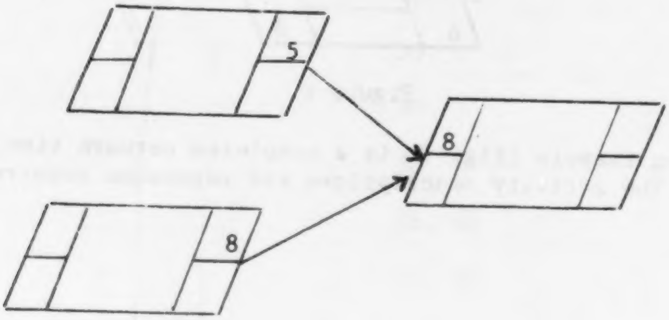


Figure 4.

c. Late Start (LS) time = Late Finish (LF) time - Activity Duration.

d. If more than one connecting arrow leaves a node, use the smallest ate Start time at the head of the arrows as the Late Finish for the node t the arrow's tail (fig. 5). Remember, on this pass through the network, ou are generally working from right to left, going from the head to the ail of the connecting arrows. This is exactly the opposite of the early ime pass through the network.

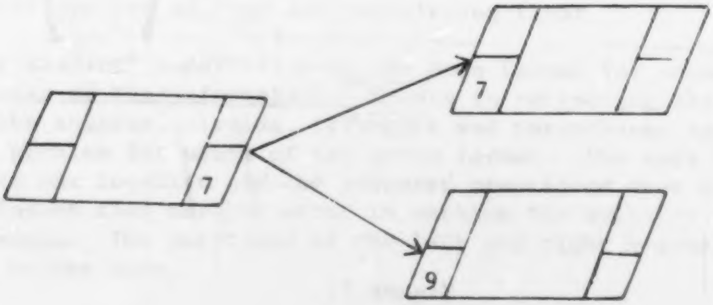


Figure 5.

e. Critical activities are those activities in which both pairs of times (ES & LS and EF & LF) are equal. The critical activities will form a continuous chain or path through the network and are usually marked by a heavy or double line.

f. The Total Float time available for any activity can be calculated by taking the difference between any pair of times (ES & LS or EF & LF), as shown in the figure 6 sample.

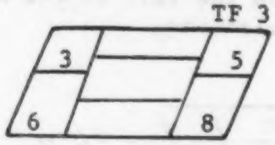


Figure 6.

The following example (fig. 7) is a completed network time analysis for a project. The activity descriptions and resources required have been omitted.

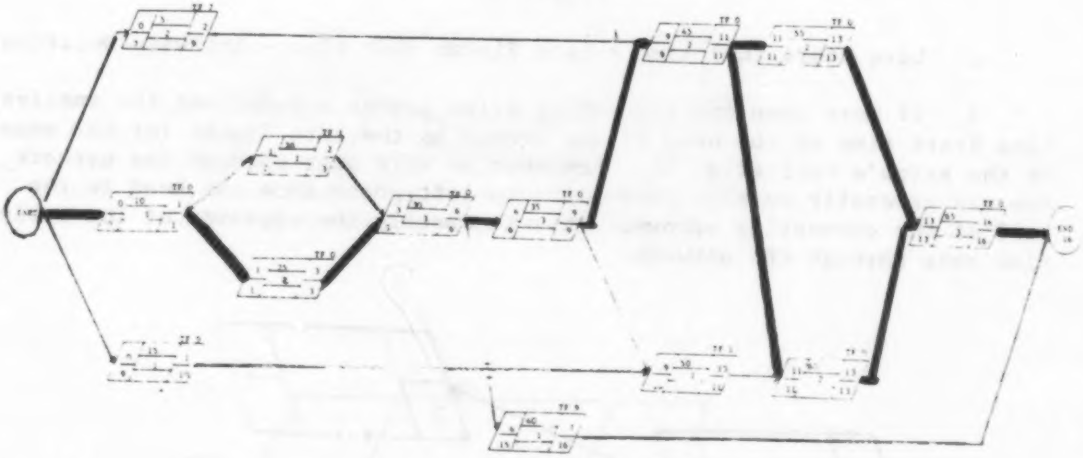


Figure 7.

The next major step is the development of the schedule. There is only one significant difference between the two methods. In the node format, in order to show the relationship of one activity to others. we must list the activity numbers of all succeeding activities related to the one listed. Using the previous example, the schedule listing would appear as shown below.

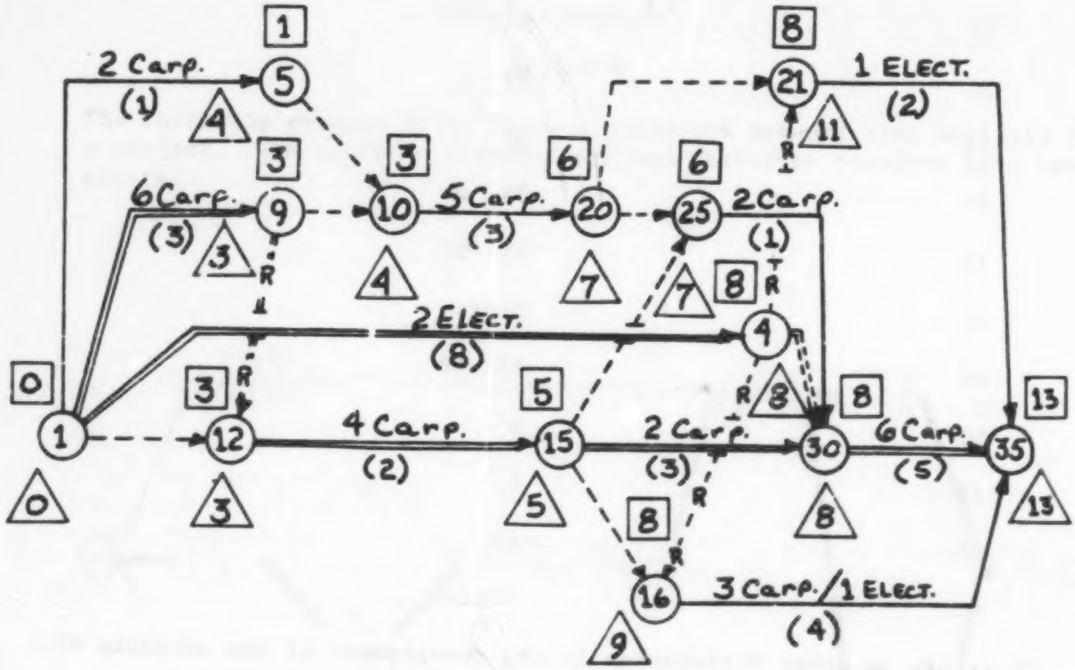
ACTIVITY NUMBER	SUCCEEDING ACTIVITIES
Start	5, 10, 15
5	45
10	20, 25
15	50
20	30
25	30
30	35, 40
35	45, 50
40	Finish
45	55, 60
50	60
55	65
60	65
65	Finish

There are no other differences in the development of the schedule or the identification of free and interfering float.

The distinct superiority of the node format for scheduling is the conciseness of the information. Errors in extracting the activity data amidst the squares, circles, triangles and parentheses have always been a serious problem for users of the arrow format. The node has all the information in one location and the proposed preprinted node will also eliminate the confusion that used to occur in marking the activity time frames on the schedule. The positions of the left and right brackets are already printed on the node.

RESOURCE CONSTRAINING

The manual technique for balancing a schedule due to limited resources and updating the network has always caused confusion because of the profusion of dummies required to show the new constraints (fig. 8). While no method can eliminate all the problems associated with limited resources, the node method greatly reduces the confusion. The resource dummy is the only dotted line used and is easily identified as a constraint caused by resource limitations (fig. 9). There is no change in the identification process used to determine the source of the resources required to enable the activity to be accomplished. Both figures are the same example.



1
2 Carp.
(1)
5
4
3
6 Carp.
(3)
9
3
R
3
10
4
5 Carp.
(3)
6
20
7
8
21
1 ELECT.
(2)
11
R
6
25
2 Carp.
(1)
7
8
R
4
2 ELECT.
(8)
R
0
1
0
3
12
3
4 Carp.
(2)
5
15
5
2 Carp.
(3)
R
R
8
8
30
8
6 Carp.
(5)
13
35
13
8
R
16
9
3 Carp./1 ELECT.
(4)

Figure 8.

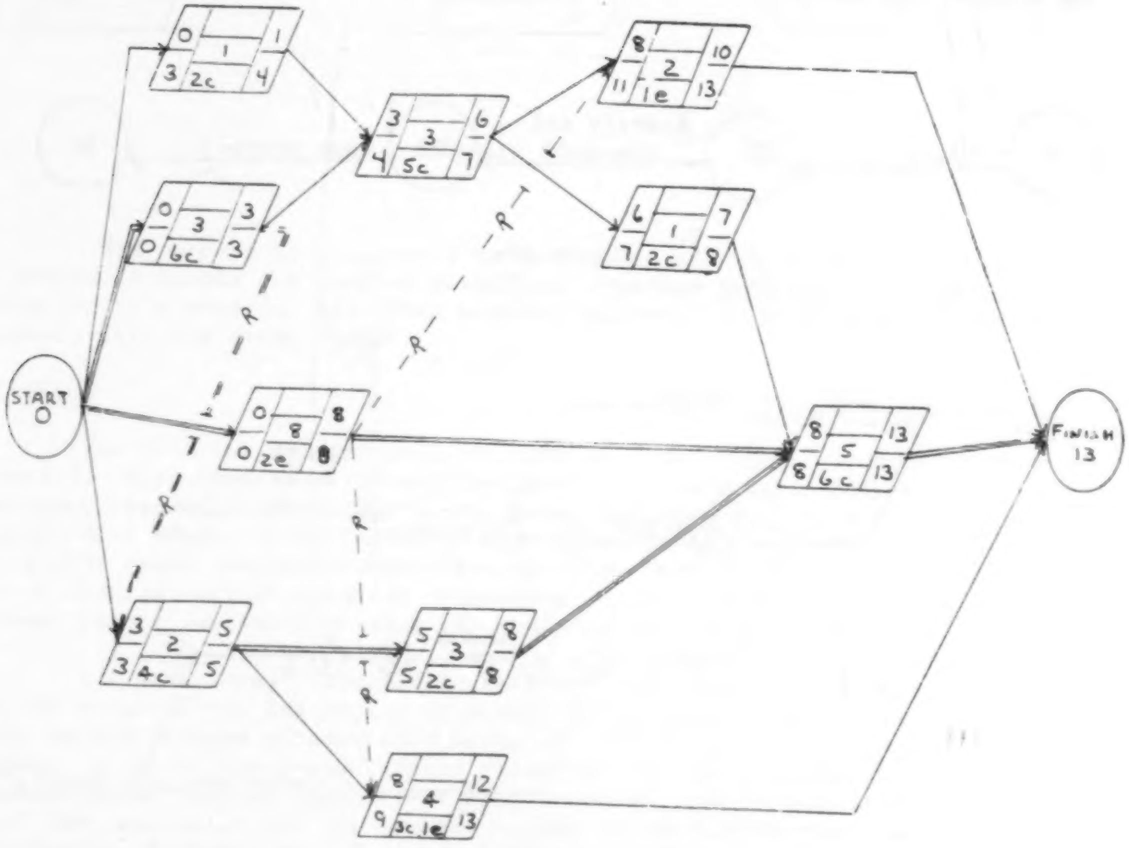

START
0
0 1 1
3 2c 4
0 3 3
0 6c 3
0 8 8
0 2e 8
3 2 5
3 4c 5
3 3 6
4 5c 7
5 3 8
5 2c 8
8 4 12
9 3c 1e 13
8 2 10
11 1e 13
6 1 7
7 2c 8
8 5 13
8 6c 13
FINISH
13
R
R
R
R
R
T
T
T

fig. 9

LAG FACTORS.

A major problem with the activity-on-the-arrow occurs when it is desired to show that one activity does not have to be completely finished before a succeeding activity can be started. One technique used has been to break the activity into parts to show the relationship. This creates a ladder effect as illustrated in the following example (fig. 10) of a road project in which only 1/4 of an activity must be completed before the succeeding activity may start. This 'common sense' procedure is extremely confusing and awkward to diagram. It also dramatically increases the size of the schedule.

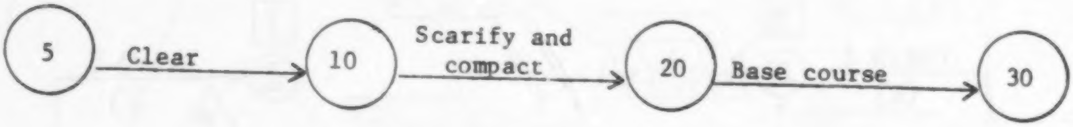

5
Clear
10
Scarify and compact
20
Base course
30

Figure 10a.

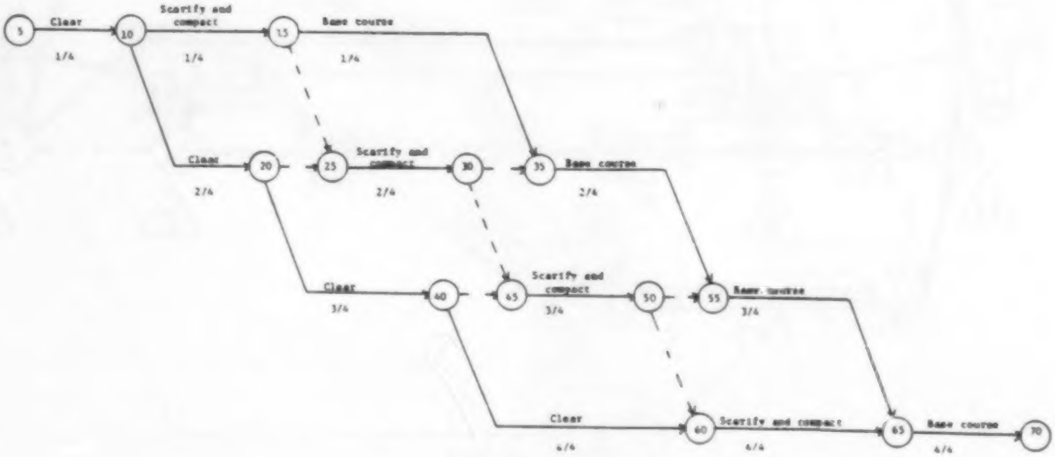

5
Clear
1/4
10
Scarify and compact
1/4
15
Base course
1/4
Clear
2/4
20
25
Scarify and compact
2/4
30
35
Base course
2/4
Clear
3/4
40
45
Scarify and compact
3/4
50
55
Base course
3/4
Clear
4/4
60
Scarify and compact
4/4
65
Base course
4/4
70

Figure 10b.

In the node format the entire situation can be solved by a couple of simple notes indicating how much of the activity must be completed before the next one can start. This is called a lag factor. We will define a lag factor to mean that the start of the following activity lags behind the preceding activity by some part of the activity duration.

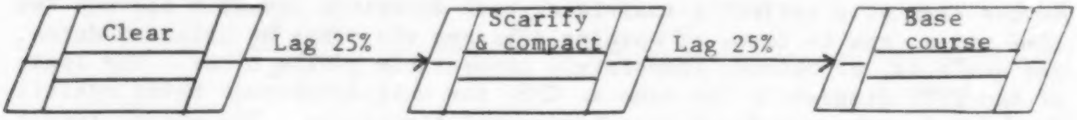


Figure 11.

This concept is elaborated in many texts and there are established procedures to handle any complex situation. For our purposes this simple indication is a powerful tool when measured against the profusion of dummies necessary with the arrow format.

CONCLUSION.

The military manager does not have to limit himself to an either-or situation. Both formats of network analysis have advantages and ardent advocates. Although CPM in the arrow format has been used in military planning for many years, it has never received widespread acceptance and usage. Some of the major complaints have been the time required to prepare the network diagram: effort involved in posting changes and the confusion caused by dummy arrows, especially among the non-commissioned officers.

The node format (precedence diagram) overcomes these complaints and adds the power of the lag factor to enable the planner to show more information on the diagram without increasing the effort required to create the diagram. With our continued limited resources the need for precise control of resources throughout the project will increase, and network analysis is one of the best tools for the manager to use in controlling the movement and distribution of resources. The node format of network analysis greatly simplifies the graphic portrayal of the project and its use can significantly increase the military manager's effectiveness.

CONSTRUCTION PROJECT TASK SCHEDULE

DEFINITION AND APPLICATION

Engineer Combat Battalions (Heavy) in Germany currently use a method of construction scheduling referred to as the Construction Project Task Schedule or CPTS. A CPTS is simply a network diagram which graphically scales each of a project's individual task durations normally against two time units, one in terms of working days and the other as calendar dates. One scale is, of course, immediately convertible to the other. The logic of the CPTS diagram is the same as CPM, the only difference being activity duration lengths are drawn to a horizontal time scale. The visual result is that tasks which are longer in duration will appear longer in length than shorter duration tasks on the same network. Because the CPTS format is more visual than a basic CPM network, the critical path (or longest path) will become obviously more apparent, as other paths will be shorter and have slack time represented by short continuous dashes. This visual picture that the CPTS time-scaled network depicts of construction logic makes it an ideal tool for project management. This is especially true for supervisory personnel who lack technical CPM knowledge, but still must understand "what happens when" in order to complete a project on schedule. Additionally important, the CPTS format provides an excellent medium for briefing VIP's as to a project's planning and current work progress.

NETWORK COMPARISONS

The CPM network represented in figure 1 would be depicted on a CPTS diagram as shown by figure 2. In the CPTS diagram, note the arbitrary use of 1 July 1977, as the project starting date and the use of a 5-day work week.

CPM Network

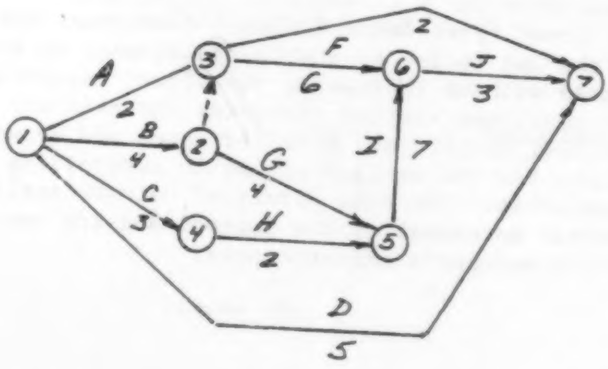


Figure 1.

July 1977

Calendar Days	1	4	5	6	7	8	11	12	13	14	15	18	19	20	21	22	25	26
Project Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

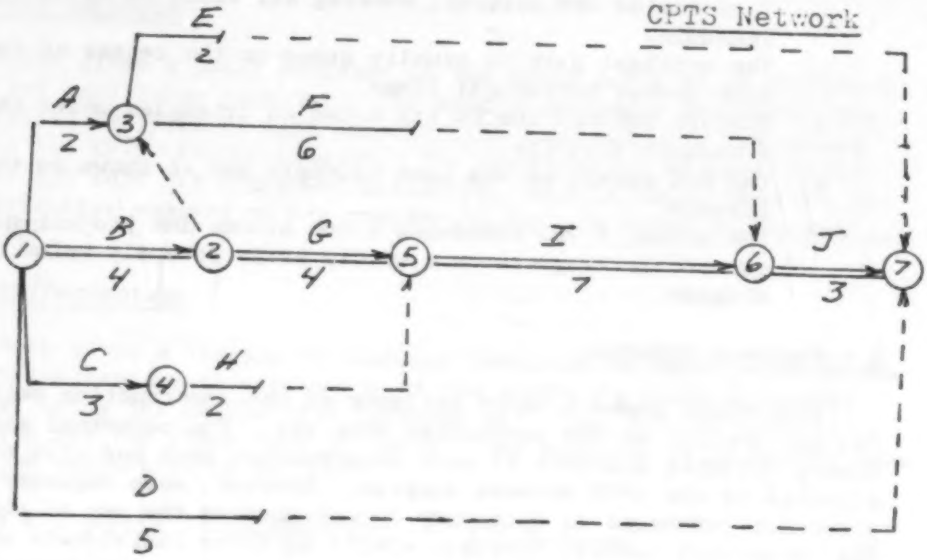


Figure 2.

As can be seen from the example diagram, the CPTS format graphically portrays a project's CPM logic on a daily basis, using an early start schedule. This is extremely useful for project supervisors who must report, usually on a weekly basis, what percentage of their project is actually completed versus what is scheduled to be completed. This time-scaled type of network additionally provides a convenient device for scheduling labor and equipment needs, and quality control tests, other important features of the CPTS format.

CPTS FORMAT

The Construction Project Task Schedule (CPTS) format is simple and direct, usually drawn on a single sheet of blueprint size paper. Refer to drawing #1 (reduced in size) when reading through the following explanation of each of the CPTS's information blocks:

A - Heading

1. Construction unit.
2. Project number.
3. Estimated date to start construction (EDS).

4. Estimated date to complete construction (EDC).
5. Project title.

B - Network Diagram

1. Time-scaled CPM network, showing all tasks on an early start schedule.
2. The critical path is usually drawn in the center of the diagram with double horizontal lines.
3. Quality control checks are noted in triangles under the applicable scheduled activity.
4. The EDC should be the last calendar day as shown on the network diagram.
5. The actual % vs. scheduled % row allows the project manager to record his progress on a weekly basis directly below the CPTS diagram.

C - Manpower Schedule

This block shows a daily estimate of the construction skills required for the project on any particular work day. The personnel estimates come from a detailed analysis of each construction task and will correspond directly to the CPTS network diagram. However, some engineering and construction judgement is necessary in calculating the use of the labor pool. The labor pool concept consists simply of those individuals who are available to work, but due to the project's scheduling requirements are unable to work in their particular construction skill. This is a common problem on most job sites, especially with labor intensive tasks such as placing concrete, painting, handling construction materials, and setting-up or cleaning-up a project. A civilian contractor would simply hire or fire personnel as he needed them, but a military foreman is usually dependent upon a fixed amount of construction skills (especially true if the project is at a TDY location). For example, suppose a project has only three MOS trained earthmoving personnel, but needed five earthmovers to efficiently complete a certain phase of construction (see task 2-3, Site Prep). A typical construction NCOIC would normally pick two other available soldiers (possibly masons or electricians, etc.) to get the job done, even though this will require a considerable amount of his attention and some OJT for the inexperienced men. This may not be the best construction technique, but it does occur to a limited extent and should be planned for by use of the labor pool calculation. The result is the project supervisor is alerted in advance to the days he will have to cross-train other available project personnel to fill in for those missing construction skills he needs.

The alternative to this method is the strict adherence to resource constraining, which shifts construction tasks and dependences upon the construction skills actually available. Unfortunately, this method will normally increase a project's duration and on many days leave troops standing around without jobs, as it assumes that a soldier can only work in one construction field.

D - Equipment Schedule

This block gives a daily estimate of the hours and type of equipment needed on any particular work day. The hourly equipment estimates come from a detailed analysis of each construction task and will correspond directly to the CPTS network diagram. The construction manager should remember to add into his equipment estimates, vehicle usage required for the administrative support of his project to include troop appointments, training, etc.

E - Manhours/Percentage

This block gives a listing of manhours required for each construction task and the percentage it represents of the project's total manhours. For example, using the sample CPTS (drawing #1), task 2-3 (Site Prep), required five men for three days or 5M-3D. The manhours required for this task would be calculated as follows:

$$5 \text{ Men} \times 3 \text{ Days} \times 7 \frac{\text{Working Hours}}{\text{Day}} = 105 \text{ Manhours}$$

The percentage of the total project's manhours would be calculated by:

$$\frac{\text{Manhours (task 2-3)}}{\text{Total Project's Manhours *}} = \frac{105 \text{ Manhours}}{3038 \text{ Manhours}} = 3.46\%$$

*Supervision is not included in this total, as it is not considered to contribute directly to physical construction progress.

F - Project Scope

A brief concise statement as to the extent of construction. A site sketch may be added to give greater clarity.

G - Project Cost

Calculated by adding the following:

1. Material Cost (from BOM)
2. TDY Manpower Cost = Men Available x Calendar Duration x TDY Rate
3. Equipment Cost (from Block D)

H - Assumptions

This block is extremely important as it lists those assumptions which will directly affect the estimates concerning manpower, weather, materials, equipment and the number of work days per week. These assumptions must be justifiable and will be viewed closely if a project extension is requested.

I - Quality Control Tests

This block is simply a listing and schedule of those tests which are required by the specifications and local construction SOP's. Results should be recorded directly onto the CPTS as they occur.

J - Signature Block

Normally signed by the following:

1. Platoon Leader/Project Officer
2. Unit Commander
3. Battalion S3
4. Group S3

UNIT: Co C, 249 Engr Bn (Hy)

PROJECT No.: 4000 A-B5 124

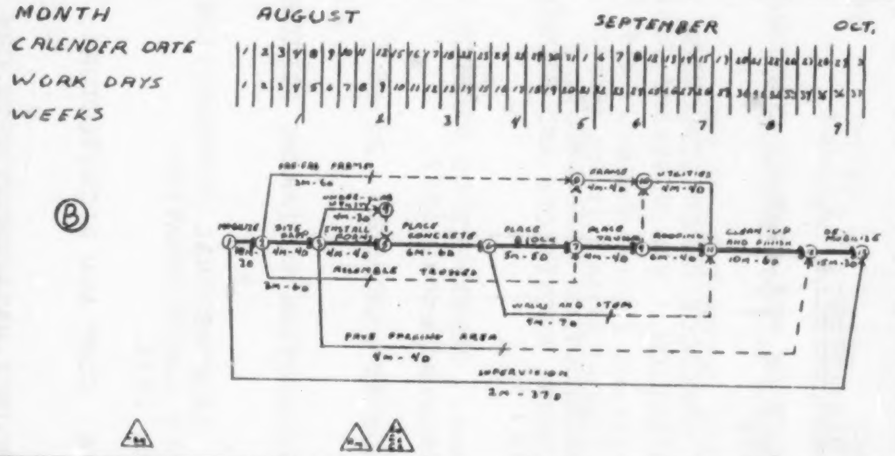
PPOJECT TITLE: BLOCK HOUSE #1

Ⓐ

EDC 03 OCT 85

Ⓔ

ITEM #	DESCRIPTION	MAN-HOURS	%
1-2	MOBILIZE	252	2.29
2-3	SITE PREP	105	3.46
2-7	ASSEM TRUSSES	126	4.15
2-8	PREFAB FRAMES	126	4.15
3-4	GROUND UTILITIES	84	2.76
3-5	INSTALL FORMS	112	3.69
3-12	PAVE PARKING AREA	308	10.14
5-6	PLACE CONCRETE	252	8.29
6-7	PLACE BLOCK	175	5.76
6-11	WALKS/STEPS	196	6.45
7-9	PLACE TRUSSES	112	3.69
8-10	FRAME	112	3.69
9-11	ROOFING	168	5.53
10-11	UTILITES	112	3.69
11-12	FINISH	420	13.82
12-13	DEMOBILIZE	378	12.44
	SUB TOTAL	3038	100
1-13	SUPERVISION	518	N/A
	PROJECT TOTAL	3556	100


Ⓑ
MONTH
AUGUST
SEPTEMBER
OCT.
CALENDER DATE
WORK DAYS
WEEKS
1
2
3
4
5
6
7
8
9
MOBILIZE
2M-30
SITE PREP
4M-40
PRE-FAB FRAMES
3M-60
UNDER-SLAB UTILITY
4M-30
INSTALL FORMS
4M-40
ASSEMBLE TRUSSES
3M-60
PLACE CONCRETE
6M-60
PLACE BLOCK
5M-50
FRAME
4M-40
UTILITIES
4M-40
PLACE TRUSSES
4M-40
ROOFING
6M-40
CLEAN-UP AND FINISH
10M-60
DE-MOBILIZE
15M-30
WALKS AND STEPS
4M-70
PAVE PARKING AREA
4M-40
SUPERVISION
2M-370

SCHEDULED %	
ACTUAL %	

Ⓒ MANPOWER SCHEDULE (MAN-DAYS)

CARPENTERS	6 6 6 6 6 6 6 6 4 4 4 4 4 6 6 6 6 6 6 6 6 6 2 2 2 2 2 2 2 6 6 6
MASONS	5 5 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 2 2 2 2 2 2 5 5 5
PLUMBERS	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
ELECTRICIANS	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
EARTH MOVER	3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 2 2 2 2 2 2 3 3 3
LABOR POOL	2 2 2 1 1 1 1 2 2 2 2 2 2 1 1 1 2 2
SUPERVISION	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
TOTAL	20 20 13 13 13 20 20 20 20 13 14 14 14 14 14 15 11 11 11 11 14 14 20 20 12 12 12 14 12 12 18 12 12 12 [illegible] 20 20

Ⓓ EQUIPMENT SCHEDULE (HOURS)

1/4 TON TRK	3 3 3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 3 3 3
2½ TON TRK	3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3 3 3
5 TON TRK	3 3 3 1 1 1 1 1 1 3 3 3 3 1 1 1 1 2 2 2 2 3 3 3
250 CFM	8 8 8 4 4 4 4 4 4
16J MIXER	4 4 4 4 4 4 5 5 5 5 5
BACK HOE	6 6 6 4 4 4 4 6 6 6 6 3 3 3 3 3 3
PAVER	4 4 4 4 4
HYSTER ROLLER	4 4 4 4 4
10 TON STEELWHEEL	4 4 4 4 4
20 TON CRANE	3 3 3 4 4 4 4 4 4 6 6 6 6 6 6 3 3 3

Ⓕ

PROJECT SCOPE: Project consists of constructing a 30'x50' building on a concrete slab, with roof trusses and a paved parking area. Building will include all utilities: electricity, water and sanitation.

Ⓖ

PROJECT COST:

Material = $50,000 (BOTTOM)

Manpower (TDY cost)

= 20 men x 64 days x $\frac{\$2.00}{\text{days}}$

= $2560.00

Equipment Cost = $1612.45

TOTAL PROJECT COST = $54172.45

ASSUMPTIONS Ⓗ

1. Platoon Strength - approximately 15-20 SM for the duration of the project
2. Weather - because the majority of the work is outdoors, one work day per week will be lost.
3. Materials - all materials are to be available at the start of construction. Additional materials will be requested thru the local F.E.
4. Equipment - special tools will be made available during the project

Ⓘ **QUALITY CONTROL TEST**

ITEM	TEST	DATE SCHED	DATE ACTUAL	RESULTS DESIRED	RESULTS ACTUAL
C_s	SLUMP	15 AUG		3-4 in	
C_c	CYLINDER	15 AUG		3000 PSI	
C_B	BEAM	15 AUG		900 PSI	
A_m	MARSHALL	11 AUG		S.G. 2.1	
C_m	CBR SUBGRADE	15 AUG		15	

= 508 MAN-DAYS

TOTAL HOURS x	COST/HOUR =	COST
49	$2.00	$98.00
80	2.48	198.40
45	2.95	132.75
48	2.35	156.00
49	3.20	156.80
76	4.00	304.00
20	3.20	64.00
20	3.25	65.00
20	3.25	67.00
78	4.75	370.50
TOTAL COST		$1612.45

PROJECT SUPERVISOR Ⓙ	UNIT COMMANDER	BATTALION REVIEW	GROUP REVIEW
			DRAWING #1

A LIST OF BOOKS IN USAES LIBRARY & LRC

CPM

658.92 An87 1970	Antill, James M. CRITICAL PATH METHODS IN CONSTRUCTION PRACTICE. 2d ed. Wiley-Interscience, 1970.
658.5 B443	Benson, Ben. CRITICAL PATH METHODS IN BUILDING CONSTRUCTION. Prentice-Hall, 1970.

CONSTRUCTION MANAGEMENT

658.4032 Ah85	Ahuja, H. N. CONSTRUCTION PERFORMANCE CONTROL BY NETWORKS. Wiley, 1976
658.92 B643 Ref	Bonney, John Bruce. HANDBOOK OF CONSTRUCTION MANAGEMENT AND ORGANIZATION. Van Nostrand Reinhold, 1973.
658.404 B963	Bush, Vincent G. CONSTRUCTION MANAGEMENT; A HANDBOOK FOR CONTRACTORS, ARCHITECTS AND STUDENTS. Reston Pub. Co., 1973.
658.92 C625	Clough, Richard Hudson. CONSTRUCTION PROJECT MANAGEMENT. Wiley-Interscience, 1972.
690 C766	THE CONSTRUCTION INDUSTRY HANDBOOK. 2d ed. Cahners, 1973.
658.2 D746	Douglas, James. CONSTRUCTION EQUIPMENT POLICY. McGraw-Hill, 1975.
658.99 F836	Foxhall, William B. PROFESSIONAL CONSTRUCTION MANAGEMENT AND PROJECT ADMINISTRATION. Architectural Record, 1972.
658.1552 H361	Heery, George T. TIME, COST AND ARCHITECTURE. McGraw-Hill, 1975.
658.018 M72 1970	Moder, Joseph J. PROJECT MANAGEMENT WITH CPM AND PERT. 2d ed. Van Nostrand Reinhold Co., 1970.
658.5 Ob6 1971	O'Brien, James J. CPM IN CONSTRUCTION MANAGEMENT; PROJECT MANAGEMENT WITH CPM. 2d ed. McGraw-Hill, 1971.

658.092 Ob6 O'Brien, James J. & R. G. Zilly. CONTRACTOR'S MANAGEMENT HANDBOOK. McGraw-Hill, 1971.

658.92 R275 Reiner, Lawrence. HANDBOOK OF CONSTRUCTION MANAGEMENT. Prentice-Hall, 1972.

58.99 R815 Royer, King. THE CONSTRUCTION MANAGER. Prentice-Hall, 1973.

58.924 229 Teets, Robert. PROFITABLE MANAGEMENT FOR THE SUBCONTRACTOR. McGraw-Hill, 1976.

58.99 888 Volpe, S. Peter. CONSTRUCTION MANAGEMENT PRACTICE. Wiley, 1972.

58.92 ASSOCIATED GENERAL CONTRACTORS OF AMERICA,

CPM IN CONSTRUCTION; A MANUAL FOR GENERAL CONTRACTORS. 1977

TE: This is only a partial listing of the references available in the Library and is limited to publication dates in the 70's.

Early Start (ES): This is the earliest time an activity can start. The ES for an activity equals EET at the tail of an activity plus one (1).

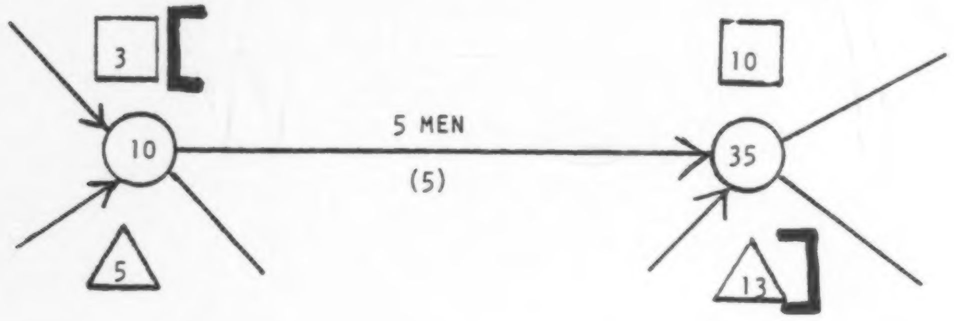
Early Finish (EF): This is the earliest possible time that an activity can end. The EF for an activity equals the Early Start plus the duration.

Late Finish (LF): This is the latest time an activity can finish and still NOT DELAY the project. The LF equals the LET (△) at the head of the activity.

Late Start (LS): This is the latest time an activity can start and NOT DELAY the project. The LS equals the LET (△) at the head of an activity minus the duration of that activity.

Interfering Float (IF): This is the time when an activity, if delayed, will directly effect one or more activities. The IF for an activity equals the difference between the LET and EET at the head of the activity.

ACT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
10-35				[5	5	5	5	5			X	X	X]		


3
10
5
5 MEN
(5)
10
35
13

ES = 4th Time Unit

EF = 8th Time Unit

LS = 9th Time Unit

LF = 13th Time Unit

IF = 3 Time Units

CREW = 5 Men

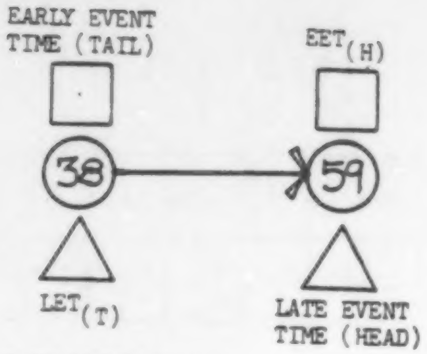
DUR = 5 Time Units

FF = 2 Time Units

REFERENCE

EET
- WORK FROM LEFT TO RIGHT
- IF HAVE CHOICE USE LARGEST
- $EET_{(H)} = EET_{(T)} + DUR$

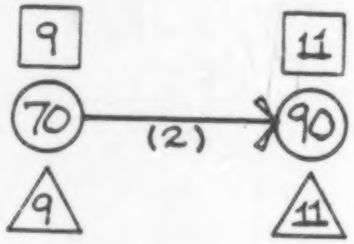
LET
- WORK FROM RIGHT TO LEFT
- IF HAVE CHOICE USE SMALLEST
- $LET_{(T)} = LET_{(H)} - DUR$


EARLY EVENT TIME (TAIL)
EET(H)
38
59
LET(T)
LATE EVENT TIME (HEAD)

CRITICAL ACTIVITY CRITERIA

ALL 3 CRITERIA MUST BE SATISFIED FOR ACTIVITY TO BE CRITICAL

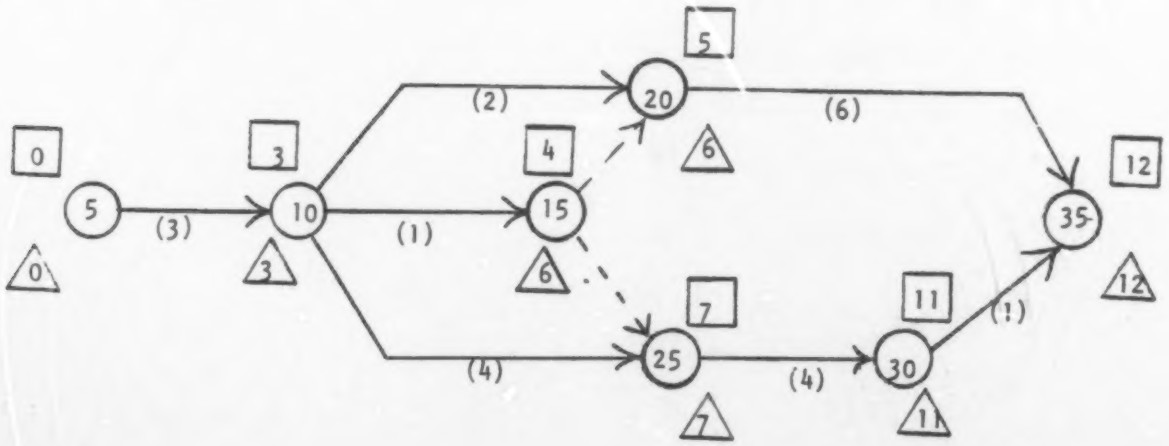
1. $EET_{(T)} = LET_{(T)}$
2. $EET_{(H)} = LET_{(H)}$
3. $EET_{(H)} - EET_{(T)} = DUR$
   OR
   $LET_{(H)} - LET_{(T)} = DUR$


9
11
70
(2)
90
9
11

** EXCEPTION: If there are ONLY dummy arrows leaving the activity, then

$$I.F. = LET_H - \text{Smallest } EET_{\text{Head of Dummy(s)}}$$

$$F.F. = \text{Smallest } EET_{\text{Head of Dummy(s)}} - E.F.$$


0
5
0
(3)
3
10
3
(2)
(1)
4
15
6
5
20
6
(6)
(4)
7
25
7
(4)
11
30
11
(1)
12
35
12